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# Generalization and decision theory.

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# Generalization and Decision Theory

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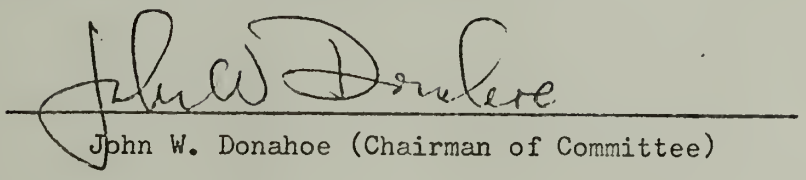

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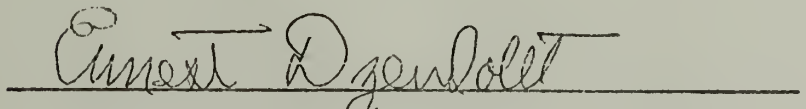

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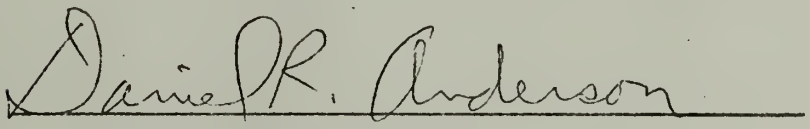

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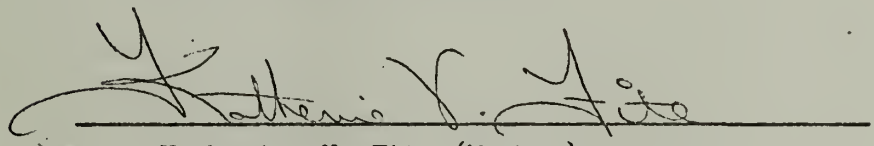

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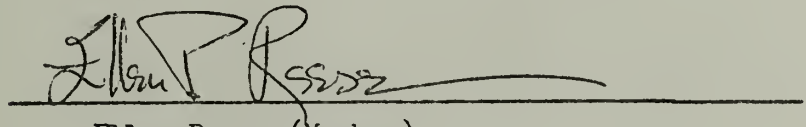

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Generalization and Decision Theory

(January 1974)

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The present experiment examined a number of generalization-discrimination phenomena. These included the changes in the response rate which occur during discrimination training, as observed in the behavioral contrast effect and the extinction of responding in the presence of the S- stimulus, and the changes in the response rate responsible for the appearance of generalization gradients, including the peak shift effect. The central question asked in each case was whether the observed rate changes were due to a change in the characteristic response patterns previously conditioned during training or due to a change in the frequency of emission of the response pattern. The criterion used for assessing this distinction was whether the modal region of the inter-response-time distribution (IRT) was shifted to a new value when the response rate changed or whether the number of responses occurring at the modal region was modulated. Pigeons were trained in a standard operant conditioning apparatus with hue stimuli either under non-discrimination conditions (single stimulus training) or discrimination conditions (multiple schedule). One set of discrimination training conditions involved the use of a variable-interval 1-min schedule (VI 1) of reinforcement in effect during S+ and, for different groups, either extinction during S- or a reduced rate of reinforcement (VI 5) schedule. A separate set of discrimination training conditions consisted

of procedures in which the rate of reinforcement was held constant but differential rates of responding were required. Subjects under this condition were trained with a multiple schedule in which a differential-reinforcement-of-high-rate (DRH) schedule was in effect during S+ and a differential-reinforcement-of-low-rate (DRL) schedule during S-. A tandem VI 1-min requirement was also imposed to hold reinforcement rate constant across all groups. Two additional groups of subjects were trained with the VI 5-min and the DRL schedules in effect during S- but with the S- stimulus further removed from the S+. The results of the IRT analysis of responding during generalization testing indicated that the generalization gradients developed due to the fact that the previously conditioned response pattern occured a greater or lesser proportion of the time during presentation of the test stimuli. The momentary rates of responding, however, did not change appreciably. For those subjects that had developed an indentifiable response for both the S+ and S- stimuli, the presentation of stimuli intermediate to S+ and S- resulted in a mixture of the S+ and S- response patterns. The peak shift effect occurred when the test stimuli adjacent to the S+ stimulus controled a higher frequency of the S+ response pattern than did the S+, itself. Although somewhat equivocal, the IRT analysis suggested that the behavioral contrast effect might also be due to an increase in the proportion of time during which the S+ response pattern is emitted. A related finding suggested that the effects of extinction on responding were due to a decrease in the frequency of the S+ response pattern rather than to a decrease in the momentary rate of responding. A final result, obtained from subjects trained

with the more disparate stimuli, indicated that the proximity of the S+ and S- stimuli was important in determining whether a depression in in the gradient occurred (inhibitory effect) or an enhancement of the gradient (excitatory effect). It was suggested that these results could be conveniently subsumed under a decision theory approach to generalization-discrimination phenomena.

# INTRODUCTION

Despite the fact that the empirical phenomenon of stimulus generalization is one of the most widely observed phenomena within the learning literature and certainly one of the most important, many controversies concerning the interpretation of generalization remain unresolved (Kalish, 1969). Of the several theoretical approaches to stimulus generalization, perhaps the most prominent is the spread of association account which has its theoretical and empirical foundations in the work of Pavlov (1927). The primary assumptions of this account are that stimuli, other than, but similar to the conditioned stimulus also become conditioned, and that this conditioning occurs decrementally as a function of the stimulus distance (along some scale) between the stimuli. These assumptions, along with other assumptions concerning the opposing processes of excitatory and inhibitory conditioning have become the foundation of the conditioning-extinction model of learning as initially proposed by Spence (1936) and Hull (1943). According to this position, discrimination performance results from a build up of excitatory strength around the positive stimulus, associated with reinforcement, and an opposing build up of inhibition around the negative stimulus, associated with extinction. Where the two gradients overlap algebraic summation of strengths occur. These theoretical processes were used by Spence (1936, 1937) to explain discrimination learning and the transposition effect which was described as occuring under conditions where the overlapping gradients result in a post-discrimination gradient such that the positive stimulus (S+) no longer possesses the greatest strength but, rather, some adjacent stimulus on the side of the gradient opposite that of the negative stimulus (S-).

The conditioning-extinction account along with the associated spread of association concept have enjoyed a good deal of theoretical utility for many years. With the introduction of intermittent reinforcement techniques which allow for repeated testing (Guttman and Kalish, 1956), a large number of studies have been subsequently devoted to investigating changes of generalization gradients following manipulation of a variety of variables. Hanson (1959) conducted discrimination training with a positive and negative stimulus from the hue dimension followed by generalization testing. The shape of the gradient showed surprisingly good support for Spence's theoretical account of transposition. An inhibitory-like depression in the gradient appeared around the negative stimulus value. The gradient at the positive stimulus also appeared somewhat depressed with the result that the gradient now showed a new peak value at an adjacent point on the side of the gradient opposite that of the negative stimulus. Hanson termed this effect the "peak shift". This result has been replicated a number of times, and Hearst (1969) has recently conducted a series of studies to determine if the shape of the post-discrimination gradient can be predicted from the interaction of observed excitatory and inhibitory gradients. These gradient interaction results have in general supported the conditioning extinction model, although a problem exists in that maximum depression has been observed to occur at the S+ value rather than at S- (Kalish, 1969).

More direct evidence for the inferred inhibition gradient has also been obtained. Honig et al (1963) conducted discrimination training using a positive stimulus from one dimension (white key) and a negative stimulus from an independent dimension (black line superimposed).

Generalization testing was then conducted along the line-tilt dimension and an inhibitory, "U" shaped, gradient was obtained. This result has also been replicated a number of times and lends additional support for the notion that an active process of inhibition exists which functions in a manner similar to the excitatory process but, of course, in the opposite direction.

Against this background of increasing support for the conditioning-extinction model with its spread of association mechanism, a number of disclaimers have been periodically voiced. One of the earlier criticisms was presented by Lashley and Wade (1946) in which they completely rejected the spread of association account of generalization. According to their interpretation, the empirical phenomenon of generalization did not represent spread of association but simply a failure to discriminate the test stimuli from the conditioned stimulus. The gradients that are obtained are the result of variable stimulus thresholds. In addition, Lashley and Wade predicted that no gradient at all would occur unless some form of discrimination training, either explicit or implicit, had been conducted. Razran (1949) joined the criticism and pointed out that, at that time, the gradients were obtained by averaging group data and what was needed was a demonstration of generalization in the single subject. The Guttman and Kalish (1956) study answered that particular criticism and in addition showed that the shape of the gradients remain essentially unaltered even after extensive testing in extinction. Lashley and Wade had earlier speculated that the effects of testing might be important in forming the gradient.

The issues have been reappraised a number of times in the light of new evidence (Mednick and Freedman, 1960; Prokasy and Hall, 1963;

Terrace, 1966; Kalish, 1969) and many of the criticisms proposed by Lashley and Wade remain viable. More recently a somewhat different tactic has been employed in interpreting the generalization-discrimination phenomena. This approach which may take the form of a decision theory model (Boneau and Cole, 1967) or a stimulus detection model (Blough, 1969; Nevin, 1970) as originally developed in the interpretation of human psychophysical data. The approach is similar to that of Lashley and Wade in that the generalization-discrimination phenomena are viewed as representing a unitary process. The observed gradients of responding are due to some variable discriminal or decision process which may be influenced by a number of variables in addition to stimulus variables (by variables affecting relative "payoff"). For the present purposes, only some of the more elementary implications of decision or detection theory will be considered. The primary assumption is that the subject responds in the presence of a stimulus according to the history of training with respect to the stimulus. Thus, when some test stimulus is presented the subject may sometime respond as if the stimulus were the training stimulus (S+) and sometimes as if it were not (or as if it were some other training stimulus). This view of the role played by the stimulus in determining behavior is similar to that of the stimulus control approach (Skinner, 1938). Rather than being regarded as a prod to respond, the stimulus is viewed as "setting the occasion" for a response to occur or, more generally, as controlling when the response will occur. The topography of the response, itself, is determined by the parameters of reinforcement and the specific contingencies in effect.

As an example of how these considerations apply to generalization,

consider the typical discrimination procedure. The subject is reinforced for responding in the presence of S+ but not in the presence of S-. Following this training, the subject is presented with test stimuli. The usual results are presented as gradients of responding with response level increasing as the test stimuli approach S+. No difficulty is encountered in those studies which have been confined to a two state response system since the basic data is in terms of the normal S+ response or the S- response. More recently, however, researchers have employed the Guttman and Kalish method and have reported rates of responding as the dependent variable. These studies have typically reported intermediate rates of responding at intermediate stimulus values. The subject is not responding either with the S+ or S- rate but with some intermediate rate which has not been previously associated with reinforcement. It is possible, of course, to treat the rate data as momentary occurences of a binary response system (i.e., responding or not responding), but a considerable body of data exists which suggests that the rate of responding, or more exactly the distribution of inter-response times (IRT's), has the characteristics of a reinforced response or operant (Morse, 1966). Under conditions where the rate itself has become the operant, the occurrence of intermediate rates is more comfortably accomodated by the spread of association account than by the decision theory model. However, we may question in these cases whether the subject does in fact show intermediate responding or whether the intermediate rates occur as a result of averaging, over trials or over time, a mixture of the characteristic rates which have been associated with the training stimuli. If this is the case, then it is consistent with the decision theory interpretation

that the gradient is produced by a variable discriminal process and not by a decremental spread of association.

One of the earlier studies which supports this interpretation was performed by Migler (1964). In this study, the subjects (rats) initialized the trial with a response to Key A which produced either a high ($S_1$) or low ($S_2$) click frequency stimulus. The high frequency indicated that an immediate response to Key B would be reinforced while the low frequency indicated that the Key B response would be reinforced only if a minimum delay of six seconds occurred. Following this training, the subjects were given generalization tests consisting of a number of intermediate click frequencies. When the average latencies of responding were plotted, typical generalization gradients were obtained which showed intermediate response latencies at intermediate stimulus values. These same results were then plotted as a frequency distribution of response latencies for each stimulus tested. The results clearly demonstrated that the subjects had not responded with intermediate latencies but only with mixtures of latencies composed of fast times ($S_1$ responses) of approximately 1-2 secs. or slow times ($S_2$ responses) of 6-7 secs. Migler concluded, "the sloping generalization gradients of response rates may be, in part, the result of inappropriate averaging procedures".

Of course an argument could be made that the Migler (1964) results were not typical since reinforcement was delivered contingent on response latency. Migler and Millenson (1969), however, obtained essentially the same results with a procedure where different response latencies were obtained by varying the density of reinforcement (VI-30 sec and VI-226 sec.) in a concurrent task. Other investigators obtaining similar

results were Crites et al (1967). These investigators examined the IRT distributions following training with a Mult (VI 1 - Ext) schedule. Their findings indicated that the only difference in the IRT distribution when S+ was present and when test stimuli were present was the greater proportion of very long IRT's (greater than 10 sec) in the presence of test stimuli. The subjects did not show a progressive shift in the modal IRT category with stimuli increasingly removed from the S+ stimulus. Sewell and Kendall (1965) and Blough (1969) report this same general finding with Blough observing that the sloping gradients were, "largely a result of the fact that at stimuli relatively distant from S+, a rather high proportion of trials yield very few or no responses". It is only by averaging over trials that the monotonically decreasing gradients are obtained.

The preceeding results indicate that a detailed analysis of behavior in situations where intermediate responding to intermediate stimuli has been reported may show that the average rates are acutally mixtures of the previously reinforced rates associated with the training stimuli. In passing, it may be noted that thses results bear a striking resemblance to the neurophysiological findings of John and Killan (1959) and John (1960, 1963). In brief these investigations have found that following training in a variety of situations with a stimulus consisting of a flickering light, a representational neural response pattern was recorded at a number of sites involving both the sensory system and nonspecific sites. This neural pattern reflected some of the characteristics of the stimulus (rate) and occurred whenever the stimulus was presented, but interestingly, when a test stimulus similar to the training stimulus was presented, the representational response of the training

stimulus was observed. Only following continued exposure did the new stimulus eventually evoke its own characteristic neural pattern. When discrimination training was given with the two stimuli (different flicker rates), subjects would occasionally respond when the S- was presented, and on these occasions the representational response of the S+ was recorded. Conversely, when the subjects failed to respond to the S+ stimulus, the evoked response characteristic of the S- was observed. When an intermediate stimulus was later presented in generalization testing, the evoked response was the representational pattern of the S+ on some trials and on other trials the pattern of the S- stimulus eventhough the stimulus presented was constant. The parallels between the neural response patterns observed by John et al and the behavioral response patterns discussed earlier are clear. In both cases, the presentations of test stimuli result in characteristic responses which were previously observed to occur in the presence of the training stimuli associated with reinforcement.

Problems for a Decision Theory

The decision theory account of generalization-discrimination phenomena encounters a number of problems in attempting to explain a variety of results within the learning literature. Some of the major problem areas will be briefly outlined and a number of strategies for their resolution suggested.

Summation The summation effect has been observed under conditions where responding has been reinforced in the presence of two separate stimuli. When the two stimuli are later presented together, the subject is observed to respond more to the compound stimulus than to either of the separate training stimuli. According to conditioning-extinction

theory, the response strengths of the separate stimuli have combined algebraically. According to decision theory, the topography of the response should be that of the response associated with one or the other of the training stimuli. Weiss (1972), however, has developed an analysis of the schedules of reinforcement in those studies showing the summation effect which is consistent with decision theory. The analysis makes the point that those operant studies reporting summation may all be described as a three component multiple schedule. Responding is reinforced in the presence of either of two stimuli and extinguished when both stimuli are absent. In addition, classical conditioning may be similarly described since reinforcement is never delivered in the absence of a CS. Thus, the absence (off-state) of either stimulus indicates non-reinforcement. When only one stimulus is presented the off-state of the other is also present and responding is depressed. When both stimuli are presented together, a higher level of responding occurs since neither off-state is present and the conflicting stimulus control condition is now removed. Weiss has supported this analysis by showing that in studies where no period of extinction occurs, the summation effect does not occur. The compound stimulus is these studies results in a response rate which is intermediate to the rate observed to occur to the training stimuli. Weiss (1969; 1972) trained subjects to respond at a high rate when one stimulus was present and at a low rate when the other was presented. Subsequent IRT analysis of responding to the compound stimulus showed that the intermediate rate which was then observed was actually composed of a mixture of the response patterns previously observed when each of the training

stimuli were presented.

Weiss' data, needless to say, offers strong support for the decision theory account of summation effects in those studies where the compound stimulus method is used. Another situation where the conditioning extinction theory predicts summation is under conditions where two stimuli from the same dimensions have been conditioned. Summation is predicted at intermediate stimulus points where the generalization gradients overlap. The evidence for summation under these conditions has, in general, been negative. Although Kalish and Guttman (1956) found a slight tendency toward summation, the more powerful procedure used by Kalish and Guttman (1959) study showed no evidence for the effect. More recently, Blough (1969) has also reported no evidence for summation.

Gradients prior to Discrimination The problem which exists here is how can a decision theory account explain the fact that generalization gradients are observed even when discrimination training has not been given. The subjects are observed to respond as if their history of training was such that responding only in the presence of the S+ had been reinforced, when, in fact, no such training has occurred. Guttman and Kalish (1956), for example, trained pigeons to respond to a colored key and found that subsequent generalization tests revealed a gradient which peaked at the training value along the hue dimension. This result is consistent with conditioning-extinction theory but not with decision theory. On the other hand, a number of studies (see Kalish 1969) have reported flat gradients following training with a single stimulus. The decision theory approach could make a plausible argument that the occurrence of peaked gradients is an artifact caused by previous,

extra-experimental, experience with the stimulus dimension or by implicit discrimination training within the experiment. The latter effect could be due to the physical location of the stimulus with respect to the response (Heinemann and Rudolph, 1963; Wunderlish and Dorff, 1965) or the testing procedure itself (cf. Kalish, 1969). However, an alternate argument is also available to the conditioning-extinction model in that the occurrence of flat gradients may be due to a masking effect resulting from control by background stimuli which is obscuring the normal shape of the gradient (Hull, 1952). No resolution of the problem is currently available since an adequate description of the controlling variables is absent.

Inhibition The process of behavioral inhibition was initially proposed by Pavlov (1927). The experimental design used by Pavlov involved delivery of reinforcement when stimulus $S_1$ was presented but not when the compound stimulus $S_1 + S_2$ was present. The $S_2$ stimulus was then paired with a third stimulus, $S_3$, which had previously been conditioned alone. The novel compound, $S_2 + S_3$ was found to elicit no responding. Pavlov described this ability of the $S_2$ stimulus to prevent responding which would otherwise occur as being due to an inhibitory effect.

Other methods of demonstrating inhibition, in addition to the stimulus compounding method, include procedures using either interdimensional or intradimensional stimuli. The interdimensional method calls for reinforcement when stimulus $S_1$ is presented and non-reinforcement when stimulus $S_2$ from some different (orthogonal) stimulus dimension is presented. The effect of inhibition is seen when generalization

tests are conducted along the $S_2$ dimension and "U" shaped gradients displaying a minimum at the $S_2$ value are obtained (e.g., Honig et al 1963).

The intradimensional procedure was previously discussed and involves the reinforcement and non-reinforcement of different stimuli from the same stimulus dimension. The inhibitory effect is inferred from the depression in the generalization gradient around the negative stimulus point, the sharpening of the gradient in this region, and the occurrence of peak shift (Hanson, 1959).

As described earlier, according to conditioning-extinction theory, the inhibitory process is viewed as being similar but opposite in direction to the excitatory process. According to the decision theory approach described here, we may simply treat the effect of non-reinforcement in discrimination training as resulting in the stimulus control of non-responding rather than the acquisition of some inhibitory influence. One major difference between the two accounts is that the concept of inhibition usually implies the existence of "below zero" conditioning, but this difference is not directly testable. In many other respects, the predictions of both accounts are similar. Decision theory views the positive stimulus as controlling some pattern of responding and the negative as controlling non-responding. When the stimuli are combined as in Pavlov's demonstration, the S- may control and result in reduced responding. In the inter dimensional procedure, the control by S- will diminish as the stimulus is varied in generalization testing and a "U" shaped gradient may appear. When intradimensional training has been used, the depression in the gradient and peak shift will occur due

to the proximity of the S+ and S- stimuli which results in the intermediate stimuli and even the S+ itself being responded to as if they were S-. In each of these cases, the examination of patterns of responding by means of IRT distributions should reveal a mixture of the representational patterns which are characteristic of either the S+ or S- stimuli. Although a finding of this type would support decision theory, it would do so primarily at the expense of the spread of association concept. The concept of inhibition would not be directly implicated.

In the studies described above, the measure of inhibition is simply the relative amount of non-responding which is observed when the S- stimulus is presented. A test of the inhibition concept is difficult under these conditions, however, a test may be possible by using procedures which result in inhibition but not in a zero response rate. One such procedure involves the tactic of reducing but not completely eliminating the delivery of reinforcement when S- is present. Using this procedure, all of the characteristics of inhibition have been obtained; depression of the gradient, peak shift, and the "U" shaped gradient. The procedure has typically used a VI 5 min. schedule with the S-. Under these conditions, conditioning-extinction theory predicts that the depression in the gradients is due to a reduction of the rate while decision theory predicts that a characteristic pattern of responding will be developed by the S- stimulus.

A further difference between the two accounts may be seen in the predicted gradient shapes following training with stimuli associated with different frequencies of reinforcement. Guttman (1959) and Terrace (1968) have both obtained post-discrimination gradients showing

peak shift, etc., following training with two stimuli from the hue stimulus dimension. Multiple stimulus training was conducted using a VI 1- VI 5 schedule of reinforcement. Using similar training procedures (Mult VI 1- VI 4) but with a larger difference between stimuli (40 nm vs. 20 nm), Collins (1971) obtained a gradient showing two maxima (two excitatory gradients). A larger peaked gradient was evident around the $S_1$ stimulus (VI 1) while a smaller but clearly positive gradient appeared around $S_2$ (VI 4). It is difficult to visualize how conditioning-extinction theory could account for the occurrence of an excitatory gradient around an inhibitory stimulus. For the decision theory analysis, this result poses no problems. The peak shift and depression of the gradient which is observed when $S_1$ and $S_2$ are relatively near each other occurs because the stimuli intermediate to $S_1$ and $S_2$ and sometimes $S_1$ itself, are at times detected as $S_2$ and this results in a lowering of the rate to some average value of the $S_1$ and $S_2$ rates. When $S_1$ and $S_2$ are relatively distant, the intermediate stimuli may not be detected as either $S_1$ or $S_2$ and, thus, result in a rate lower than the $S_2$ rate. Under these conditions the double-peak gradient is observed.

Behavioral Contrast If non-discrimination training is conducted using two different stimuli (e.g., Mult VI 1- VI 1), and this training is followed by discrimination training in which responding in the presence of one of the stimuli (S-) is extinguished (Mult VI 1- Ext), then the rate of responding in the presence of the other stimulus will show an increase. This finding, termed behavioral contrast by Reynolds (1961), represents somewhat of an anomaly since the rate of responding has increased even though the frequency of reinforcement with respect to S+

has remained constant. The problem which the contrast effect poses for decision theory is similar to that posed by the summation effect. The subject is emitting a new and higher rate of responding than was previously observed and this higher rate cannot be explained on the basis of prior training. As suggested previously, however, only an IRT analysis can reveal if, in fact, a new pattern of responding has emerged. If the increased rate is not due to a shift in the modal IRT category but to a decrease in long IRT's, then this result would be consistent with decision theory. Such a result could be interpreted as showing that the subject was not displaying a new response pattern but simply displaying the previous response pattern a greater proportion of the time. This finding would have the effect of reversing the question typically posed by the contrast effect. Rather than asking why the subject shows an increase in responding following discrimination, the more appropriate question becomes why does the subject show periods of non-responding prior to discrimination training. The emphasis has now been shifted towards consideration of the variables which affect attention.

Statement of the Problem

While many of the previously discussed studies have found evidence supporting a decision theory interpretation, the procedures employed have for the most part differed substantially from the successive discrimination procedures from which conditioning-extinction theory and the spread of association concept have in recent times received their major support. The present study addressed a number of the problems outlined previously, while using the successive discrimination procedure. The principle dependent variable used was the IRT analysis of the changes in the

response pattern occurring during discrimination training and generalization testing. These included the response changes responsible for the contrast effect, for the sloping generalization gradient following non-discrimination training, and those changes which result in the post-discrimination gradient showing peak shift and the depression around the S- stimulus. In each case the central question asked was whether these changes occurred as a result of changes in the pattern of responding (the "strength of responding") or as a result of the previously established pattern of responding occurring a greater or lesser proportion of the time. The criterion used for assessing this distinction was whether the mode of the IRT distribution had shifted to a new value or whether the number of responses occurring at the modal value was modulated. A finding of the latter type would be interpreted as indicating that the frequency of occurrence of a characteristic response pattern was being modulated.

In addition to the basic discrimination condition which called for reinforcement in the presence of one stimulus and extinction of responding in the presence of a second stimulus ( and a non-discrimination group for comparison) several other training conditions were included which were designed to provide a distinctive response pattern in the presence of the S- stimulus. For one group this was accomplished by providing a reduced schedule of reinforcement when S- was presented (Mult VI 1- VI 5). As discussed earlier, this training procedure results in inhibitory effects similar to those obtained when extinction is scheduled during S-. The existence of an identifiable pattern of responding during S- enabled the examination of response changes in

order to determine if these inhibitory effects were due to mixtures of response patterns previously observed to occur in training with the S+ and S- stimuli. A third training condition was included which was also intended to provide an identifiable response pattern during S-, in this case, by directly reinforcing different response patterns during both S+ and S- as opposed to the indirect method of reducing reinforcement density. This was accomplished by imposing a schedule which reinforced responses of less than one second apart when S+ was present and responses greater than three seconds apart when S- was present (VI 1 [DRH 1] - VI 1 [DRL 3]). A comparison group which received non-discrimination training with a VI 1(DRH 1) schedule was also included.

The training conditions described above involved the use of different reinforcement schedules as the independent variable in order to establish identifiable response patterns. A second independent variable included in the study involved the use of different training stimuli. Two additional groups were trained with the VI1 - VI 5 schedule and the VI1 (DRH 1)-VI1 (DRL 3) schedule but with a S- stimulus further removed from the S+. Under this condition it was expected that the inhibitory effects observed during generalization testing would be attenuated since the stimuli in the region of S+ and S+ itself would be less frequently detected (or responded to) as S- and the gradient would not appear depressed. If the stimuli were sufficiently far apart, the intermediate stimuli would not be detected as either S+ or S- and the double-peaked gradient discussed earlier should result.

# METHOD

## Subjects

The subjects consisted of 21 male White Carneaux pigeons, experimentally naive and approximately five years of age, obtained from Palmetto Pigeon Plant, Sumpter, S. C. The subjects were maintained at approximately 75% of their free feeding body weight throughout the experiment.

## Apparatus

A standard Lehigh Valley pigeon operant chamber was used with masking noise provided at an intensity level of 80 db. The chamber was located in a separate room from programming equipment and encased in a sound attenuating hull. An extra house light was provided and the resultant illumination of the chamber panels had an average value of 1.6 ft-L (5.5 $cd/m^2$).

The stimulus consisted of a .25 in. patch of colored light projected on a ground glass screen placed immediately behind the response key. The stimulus light was supplied by an interference filter monochromator constructed as described by Wright (1972) except that a tungsten-halogen light source was used. The monochromator was calibrated for spectral emission by using the interference monochromator as the light source for a Bausch and Lomb monochromator. At each spectral setting throughout the range to be used, the Bausch and Lomb instrument was adjusted for maximum light intensity by visual inspection and the wavelength value noted. The obtained spectral values agreed closely with the predicted values computed, based on the angle of incident light of the interference filter (Wright, 1972).

The intensity of the stimulus light was adjusted at various points of the spectrum by introducing neutral density filters (Kodak Wratten) in the light path. The value of the filter used was computed by adjusting for the spectral emissivity of the tungsten source and for the photopic sensitivity of the pigeon (Blough, 1957) at each value used. Based on the computations, the training stimuli did not differ more than .05 log units in intensity and the testing stimuli by not more than .10 log units. The measured luminance of the stimulus was approximately 9 $cd/m^2$.

The response key required a force of 25 g applied through a distance of 2 mm as measured from the center of the key.

Procedure

All subjects were trained to key peck by the method of successive approximations. On the first day of pretraining, subjects were given habituation training by being placed in the chamber for approximately 15 mins. and allowed to eat their daily ration of grain from the raised hopper. On the second day the subjects were shaped to key peck and given 50 reinforced responses. All training stimuli were introduced at this time in order to avoid any unintended differential responding. The third day consisted of training with intermittent reinforcement by gradual increments of the number of responses required for reinforcement throughout the session. A total of 50 reinforcements were delivered and the maximum response requirement was VR 15. The fourth day of pretraining consisted of training with a VI 30 sec. schedule and 50 sec. stimulus periods separated by 10 sec. time-out periods. A total of 30 periods were allowed. Reinforcement consisted of 4 sec. access to mixed grain.

Following pretraining, all subjects were placed on their respective training schedules for the next eight days. For the single stimulus condition, this consisted of 25 stimulus periods with a VI 1-min. schedule in effect and for the discrimination training conditions, 25 stimulus periods with each of two stimuli both with VI 1-min. schedules in effect. The VI schedules were constructed such that the probability of reinforcement was independent of the time since the preceding reinforcement (Fleshler and Hoffman, 1962). The sequence of stimulus presentations for the discrimination groups was a quasi-random sequence balanced with respect to the first-order conditional probabilities of transition between S+ and S- with the added restriction that the same stimulus was never presented more than three times successively. These training conditions were in effect for all groups except where noted differently below. Prior to initial training the 21 subjects were assigned to one of seven training groups in a random manner. These training conditions involved the following procedures:

Single Stimulus Training (VI 1) Subjects received eight sessions of VI 1 min. training with a stimulus value of 554 nm. Following this training, generalization tests were conducted for the next four days using a probe testing procedure. The IRT distributions for these subjects were collected at several points during training and over the course of generalization testing. Following the generalization tests, the subjects were trained one additional day and then placed in extinction for several more days until the subject failed to respond in 10 successive stimulus periods. The extinction training provided a comparison for the effects of extinction in S- within the discrimination

training group.

Mult VI 1-Ext Training Following the initial eight days of non-differential multiple stimulus training (Mult VI 1-VI 1), these subjects received an additional eight days of Mult VI 1-Ext training. The S+ stimulus was the response key transilluminated with light of 554 nm and the S- was 569 nm. The generalization tests conducted at the end of this training phase consisted of four consecutive days of probe tests, followed by one day of return to the Mult VI1 -Ext training, and a final day of testing in extinction. The IRT distributions were collected at several points during the initial training phase (VI1 -VI1), immediately prior to, and following the introduction of discrimination training (VI 1-Ext), and prior to and over the course of generalization testing.

Mult VI 1-VI 5 Training This training condition included two groups of subjects receiving identical schedules of reinforcement but with different stimuli presented. As in the previous group, these subjects were trained for eight days with Mult VI 1-VI 1, followed by eight days of Mult VI 1-VI 5 training. Generalization testing was then begun with four days of probe testing, one day of return to Mult VI 1-VI 5, and a final day of generalization testing in extinction. For one group of subjects, the stimuli consisted of a S+ stimulus of 554 nm associated with the VI 1-min. schedule and a S- of 569 nm associated with the VI 5-min. schedule. These were the same stimulus values used with the Mult VI 1-Ext group.

The second group trained under these conditions received identical training as the first group except that the S- stimulus associated with

the VI 5-min. schedule was 591 nm rather than 569 nm. This group provided a condition with greater separation between the S+ and S- stimuli and reduced the tendency for stimuli around S+ to be detected and responded to as S-.

The testing procedure and collection of IRT distributions for the two Mult VI 1-VI 5 groups was the same as the procedure used with the previously described Mult VI 1-Ext condition.

Single Stimulus Training (VI 1 [DRH 1] ) The subjects trained under this condition received pretraining which differed from the preceding groups. Following habituation training, shaping, and one day of intermittent reinforcement training, gradually increased to VR-15, an added response contingency was effected such that only responses following a preceding response within one second (DRH 1) were effective in delivering reinforcement. The fourth day of pretraining consisted of training with the DRH schedule, and the response requirement was gradually increased to VR 15 (DRH 1). The fifth day, the requirement was gradually raised to VR 30, and the sixth to VR 40. The seventh and eight days consisted of VI 30 (DRH 1) training. For the next 10 days the subjects were trained on a VI 1 (DRH 1) schedule, followed by four days of probe testing. As in the case of the single stimulus group receiving the VI 1-min. to reinforcement schedule, the VI 1 (DRH 1) condition subjects were then placed in extinction until 10 stimulus periods occurred without responding. The stimulus present throughout training was 554 nm. This group provided a non-discrimination comparison condition for the following groups.

Mult VI 1 (DRH 1) - VI 1 (DRL 3) Training This training condition,

as in the case of the Mult VI 1-VI 5 condition, again was composed of two groups of subjects, receiving identical reinforcement schedules but differing with respect to the stimuli presented. The first group was presented with an S+ stimulus of 554 nm and an S- of 569 nm while the second group received a S+ of 554 nm and a S- of 591 nm.

The pretraining and training schedule with respect to the S+ stimulus associated with the DRH 1 schedule was the same as described above for the single stimulus VI 1 (DRH 1) training condition. On the third day of pretraining, the S- stimulus was introduced and DRL training begun. The DRL contingency operated such that only responses which occurred following a three second period in which no response occurred were effective in delivering reinforcement (DRL 3). Training continued over the next three days with the response requirement in the presence of the S- stimulus being gradually raised to VR 6 (DRL 3). This slow increase in the response requirement was necessary in order to maintain an approximately equal number of obtained reinforcements with both training stimuli. At this point in training, many of the subjects were developing a response pattern in the presence of S- which consisted of a pause of approximately three seconds followed by a short burst of responses. At this point, an additional contingency was added in an attempt to eliminate these bursts. Following a 3-sec. pause, the next response occurring operated the food hopper, however, if an additional response occurred the reinforcement in the process of being delivered aborted. Training continued for the next three days with the VR (DRL 3) requirements, followed by one day of VI-30 sec., and five days of VI 1 (DRL3). It was necessary at several points in VI training to return some of the subjects to the VR (DRL 3) schedule in order to

maintain approximate equivalence of reinforcement in the presence of S+ and S-.

The generalization testing procedure called for the presentation of each of 10 test stimuli for 50-sec. periods. The test stimuli used had the following values; 523, 532, 540, 549, 554(S+), 561, 569($S-_1$), 580, 591($S-_2$), and 600 nm. Two types of testing procedures were used, a probe procedure and an extinction procedure. The probe testing procedure required four days of testing during which each of the test stimuli were presented once each day. The test stimuli were inserted between ordinary training stimulus periods during which the appropriate reinforcement schedules were in effect. The test stimuli were inserted in a quasi-random manner such that a probe test period occurred an average of once every five trials except that at least one S+ and one S- period must have occurred since the last probe trial. In addition, no probe trials were scheduled during the first 10 trials. Two different sequences of stimulus presentation were used which were balanced with respect to whether the test stimuli were presented early or late during the test session and with respect to whether the preceding stimulus was S+ or S-. During probe testing the single stimulus training groups received a total of 45 trials while the discrimination training groups received 51 trials. The probe procedure was used in order to avoid possible disruption of the response patterns which might occur with testing in extinction.

The extinction testing was conducted in one session and consisted of an initial 10 periods of "warm-up" training (5 S+ and 5 S- periods) followed by four sequences of the 10 test stimuli. Extinction was in

effect following the initial 10 trials. The order of presentation of the test stimuli was the same order used during the four days of probe testing.

The inter-response times were logged on paper tape and analysed by computer. The resolution of recording was .10-sec. The data from the first six trials of each session was eliminated from computation.

# RESULTS AND DISCUSSION

## Generalization Gradients

Single Stimulus Training (VI 1) Following initial pretraining and eight days of training with a VI 1-min. schedule of reinforcement, the subjects receiving single stimulus training (S+ = 554nm) were tested over the next four sessions using the probe testing procedure. The generalization gradients obtained are displayed in Fig. 1. The decremental gradients appeared to be symetrically arranged around a peak at the S+ value. The variance displayed in the shape of the gradients between subjects is to be expected under these testing conditions since each test stimulus was presented for only four, 50-sec. test periods. A limited amount of testing was provided in order to avoid unintended discrimination training during testing and possible effects of extinction on the IRT distributions.

The IRT distributions obtained from testing are displayed in Fig. 2. The figure legends for IRT's mark the boundaries of the bins and indicate the maximal value of each preceding category. The bin widths are .2-sec. for the first eight categories and .4-sec. for all subsequent categories. The last category includes all responses which occurred with a greater than 6-sec. IRT. This procedure was also used for all subsequent IRT displays, and it should be noted that at times this method of plotting the data gives the appearance of an increase in the number of responses occurring in categories immediately following 1.6-sec. compared with the categories preceding the 1.6-sec. bin. This apparent increase is, in fact, due to the increase in bin size from .2-sec. to .4-sec. for IRT's

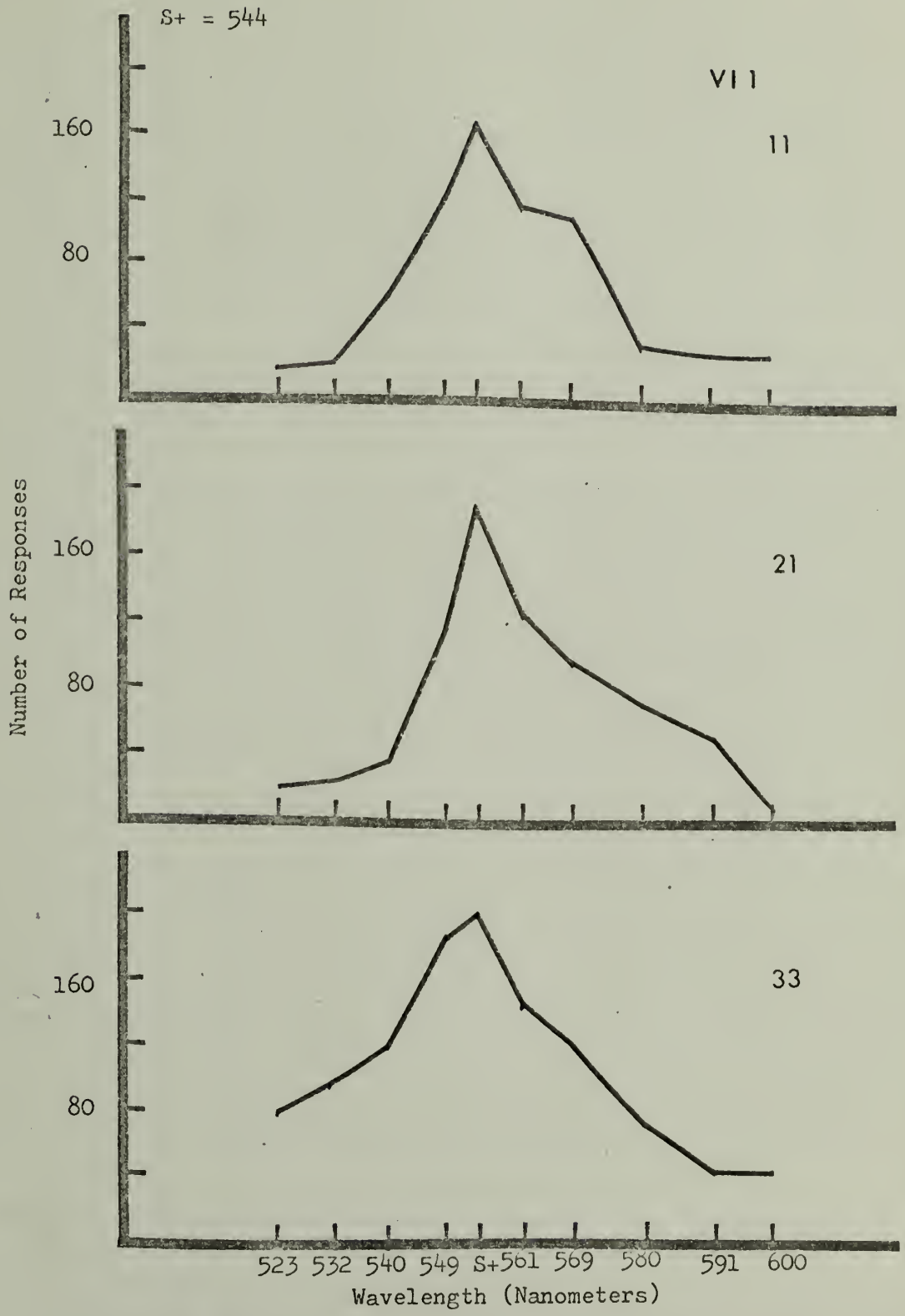


Fig. 1. Generalization gradients obtained during probe testing following VI 1 training. Subject number appears at right.

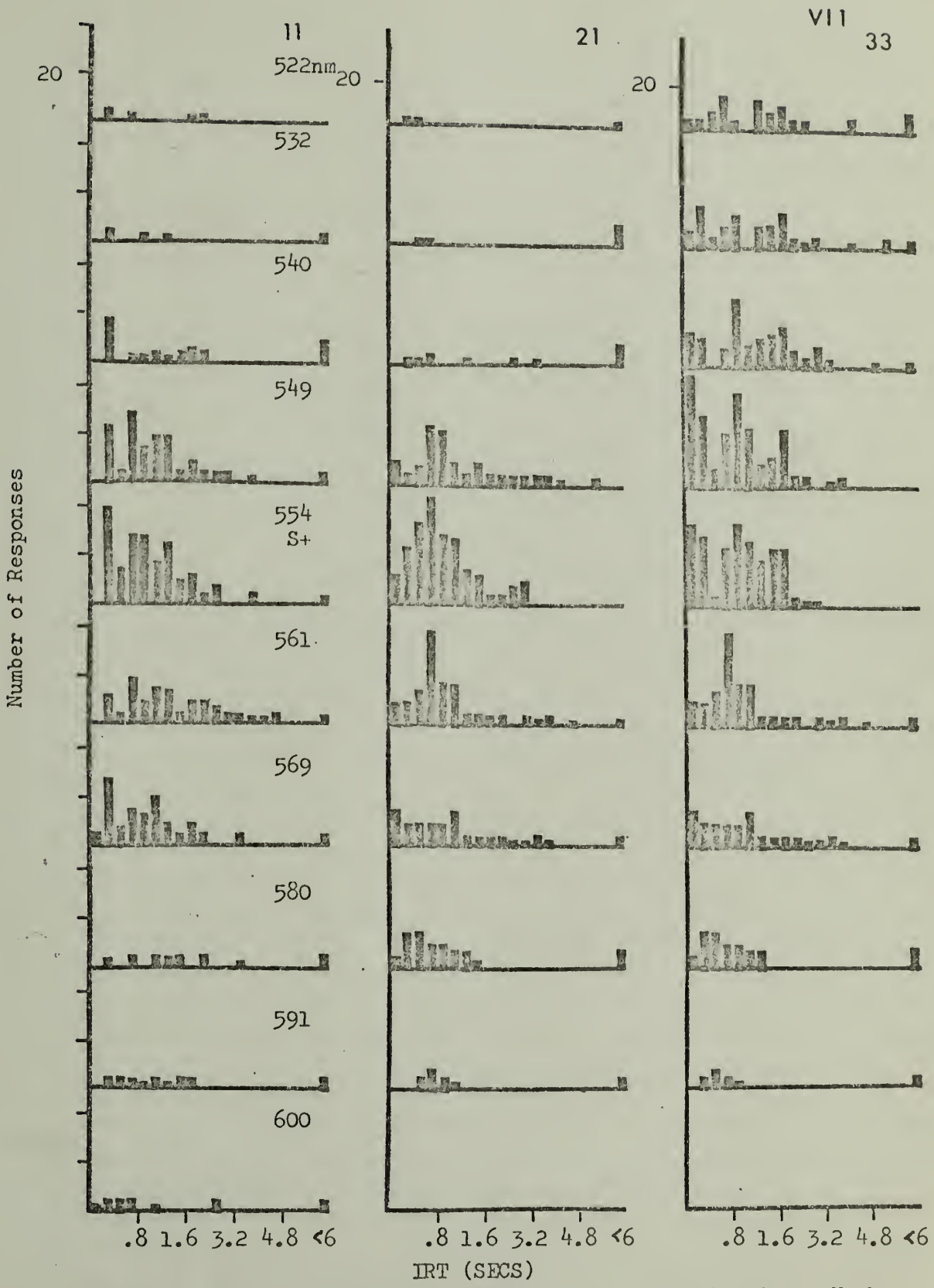


Fig. 2. IRT distributions obtained during probe testing. Numbers to the right of first column indicate the test stimulus.

greater than 1.6-sec.

The distributions displayed in Fig. 2 show that as the test stimulus becomes increasingly removed from the S+ training value (554nm) the number of responses, as indicated by the height of each IRT category, shows an orderly decrease. The proportion of responses occurring at the modal values of the distributions appear to remain relatively stable at stimulus values distant from S+ even when, as indicated in Fig. 1, a very low rate of responding had occurred. The number of responses recorded in the long IRT categories (> 6-sec.) tended to increase as the test stimulus diverged from S+, indicating an increasing tendency for long pauses in responding to occur.

These findings describe a pattern of responding occurring during generalization testing such that the response pattern developed in training with the S+ stimulus also occurs when the test stimuli are presented as indicated by the failure of the modal region of the distribution to shift. The decremental generalization gradient is obtained because of the decrease frequency of occurrence of the S+ response pattern as shown by the decreased height of the IRT bins. This description of responding as derived from the IRT displays is also consistent with observations of the subjects during testing. The birds did not appear to be emitting a consistently lower response rate to test stimuli but seemed to engage in periods of responding separated by relatively long pauses followed either by a resumption of responding (as shown in increased responding in IRT category >6-sec.) or no further responding.

These results support the decision theory interpretation of

generalization in which the subject is viewed as emitting a previously established response pattern to test stimuli but doing so less frequently. This view is to be contrasted with the spread of association interpretation in which stimuli removed from the S+ value are seen as eliciting a reduced strength of responding. Presumably, the spread of association account would predict an increased latency between responses which would generate IRT distributions showing a progressive shift in the modal response region as the stimulus became more disimiliar to the S+ stimulus. If the reduction in strength of responding was viewed as continuously changing even during testing, the IRT distribution might be expected to show low values in the S+ modal region with an increased but even distribution of responses in the longer IRT categories. Quite clearly, no subject showed either of these effects.

Mult VI 1-Ext Training The response rates obtained from two subjects trained for eight days with multiple VI 1- VI 1 during acquisition and a subsequent eight days of multiple VI 1-Ext are displayed in Fig. 3. All three subjects showed the behavioral contrast effect following the introduction of differential reinforcement. As apparent in Fig. 3, the rates of responding in the presence of the S+ (554nm) and S- (569nm) stimuli reached stability after approximately four days of training. These subjects were given another four days of training, however, in order to maintain a constant amount of experience with the stimuli for all groups.

The results of generalization testing are displayed in Fig. 4 for both the probe testing and the extinction testing procedures.

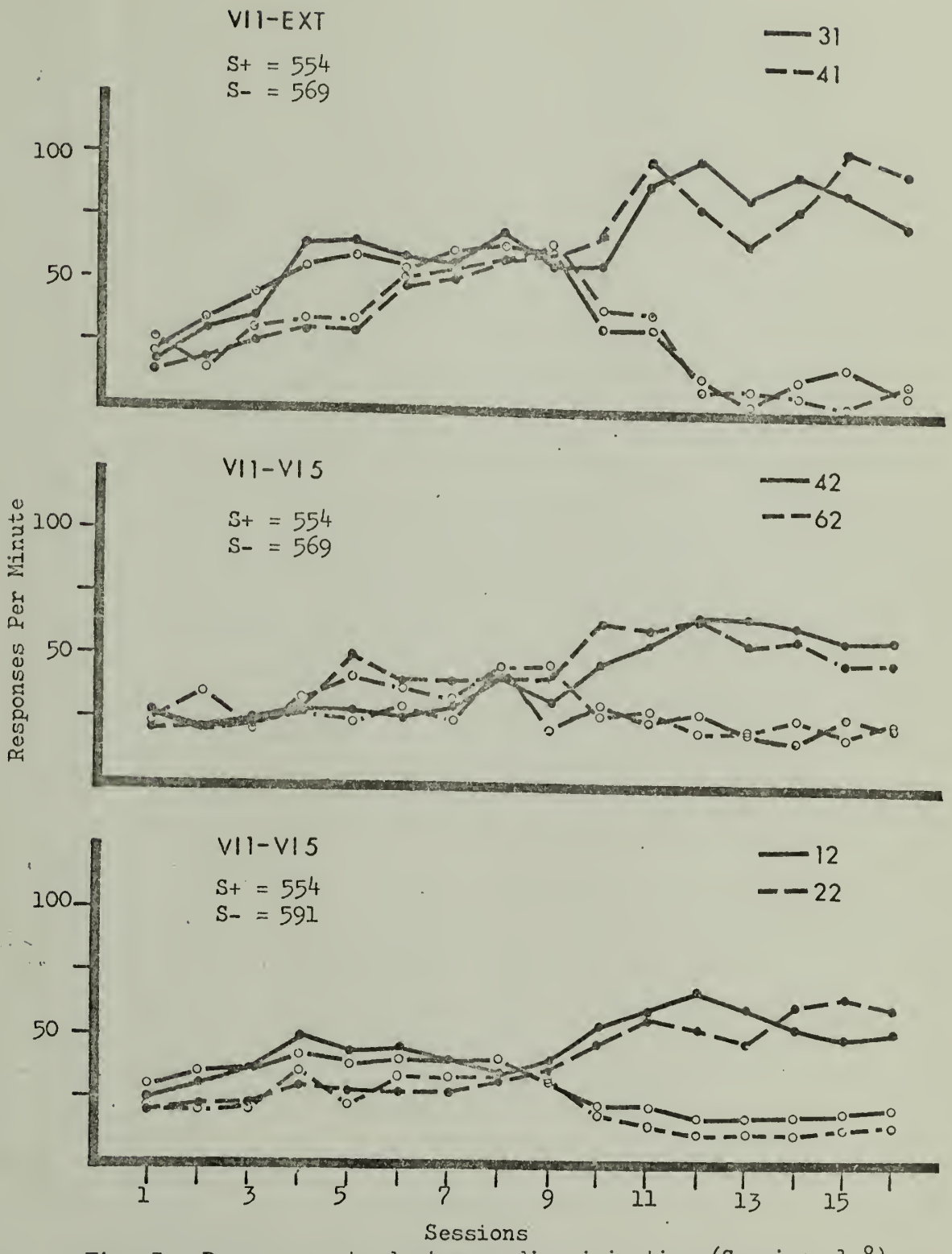


Fig. 3. Response rate during nondiscrimination (Sessions 1-8) and discrimination training (Sessions 9-16).

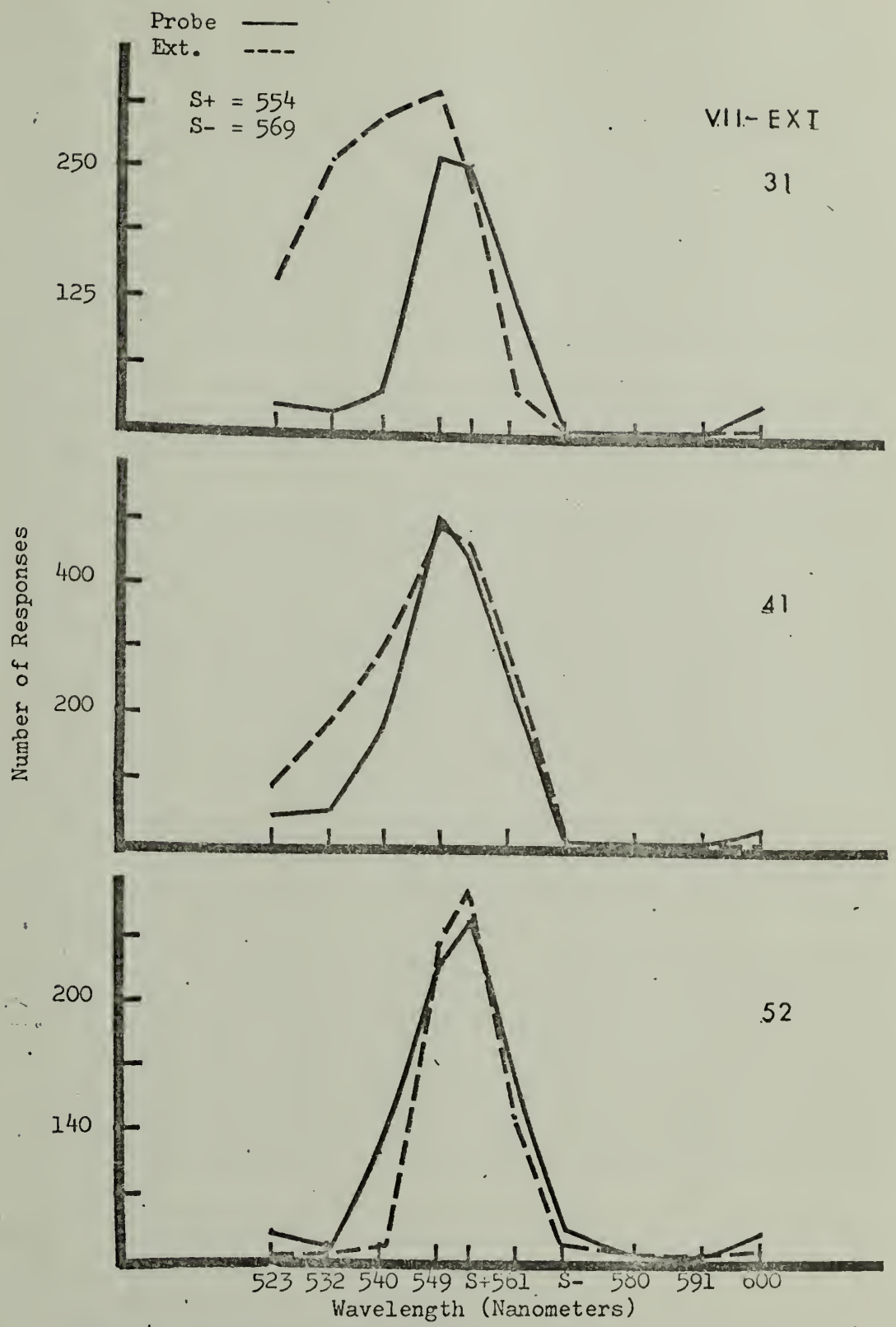


Fig. 4. Generalization gradients obtained during probe and extinction testing following multiple VI 1-Ext training.

The probe testing results showed that two subjects (31 and 41) showed the typical results of peak shift and a steepening of the gradient around S-. Subject 52 also showed the steepening effect in the region of S- but no peak shift. Quite likely, training was extended beyond the optimal period for obtaining peak shift. Pierrel and Sherman (1962) and Terrace (1966b) have found peak shift diminishes as training is extended. The extinction test gradients showed a much greater area shift for subjects 31 and 41 but somewhat less for subject 52. This increase in peak shift and area shift also occurred for one of two subjects in a preliminary pilot study using similar procedures. The relevance of this test effect will be discussed further at a later point.

The IRT distributions obtained during probe testing are shown in Fig. 5. In agreement with the results from the single stimulus training condition, the decrease in responding shown in the generalization gradient is due to a reduction in the number of responses occurring in the S+ modal region and not to any shift of the mode.

As mentioned previously, the peak shift phenomena occurred in the results of only two of the subjects (31 and 41) in probe testing and was of little magnitude for subject 31. Subject 41 showed somewhat more peak shift and the effect may be seen in the IRT distributions for the stimulus at 549nm as a slight increase in the number of responses occurring across the S+ modal region. Although the effect here is small, it is consistent with the decision theory hypothesis that the increased responding causing peak shift is not due to a shift of the S+ mode but due to an increased frequency of the S+

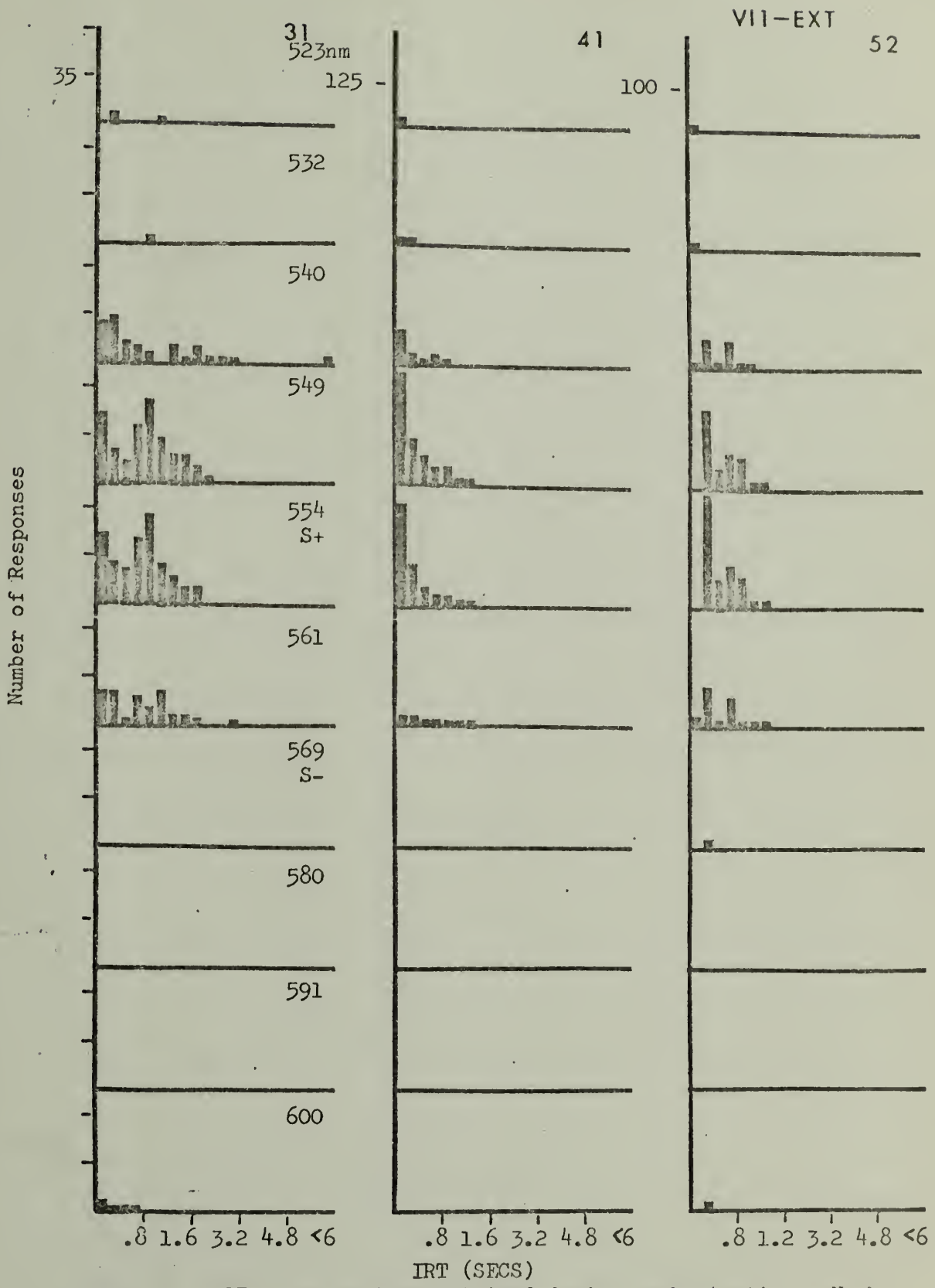


Fig. 5. IRT distributions obtained during probe testing. Numbers to the right of first column indicate the test stimulus.

response pattern. Alternately, this effect may be described as a decreased tendency for the S+ stimulus to result in the S+ response pattern. This is consistent with the hypothesis that one result of conducting discrimination training with stimuli relatively similar is that the S+ stimulus is sometimes detected as S- while stimuli adjacent to S+ (but further removed from S-) are not as frequently detected as S-. Of course, these stimuli may not be as frequently detected as S+ either, especially with extended discrimination training. This is consistent with Terrace's (1966) finding that peak shift eventually disappears with extended training.

Mult VI 1-VI 5 Training The first group trained with the multiple VI 1-VI 5 schedule was exposed to the same training stimuli (S+ = 554, S- = 569) as was the previously discussed multiple VI 1-Ext training group. The response rates occurring over the initial eight days of acquisition (multiple VI 1-VI 1) and the subsequent eight days of discrimination training (multiple VI 1-VI 5) are displayed in Fig. 3. As was found by Terrace (1966), the procedure of shifting from a more dense to a less dense schedule of reinforcement results in the same characteristics generated when extinction is scheduled. All these subjects showed behavioral contrast but of less magnitude than that occurring within the multiple VI 1-Ext condition.

The generalization gradients obtained from both probe and extinction testing are presented in Fig. 6. The results of probe testing indicated that all three subjects showed an area shift away from S-, with two subjects also showing peak shift (42 and 62). The extinction testing gradients showed basically similar results with

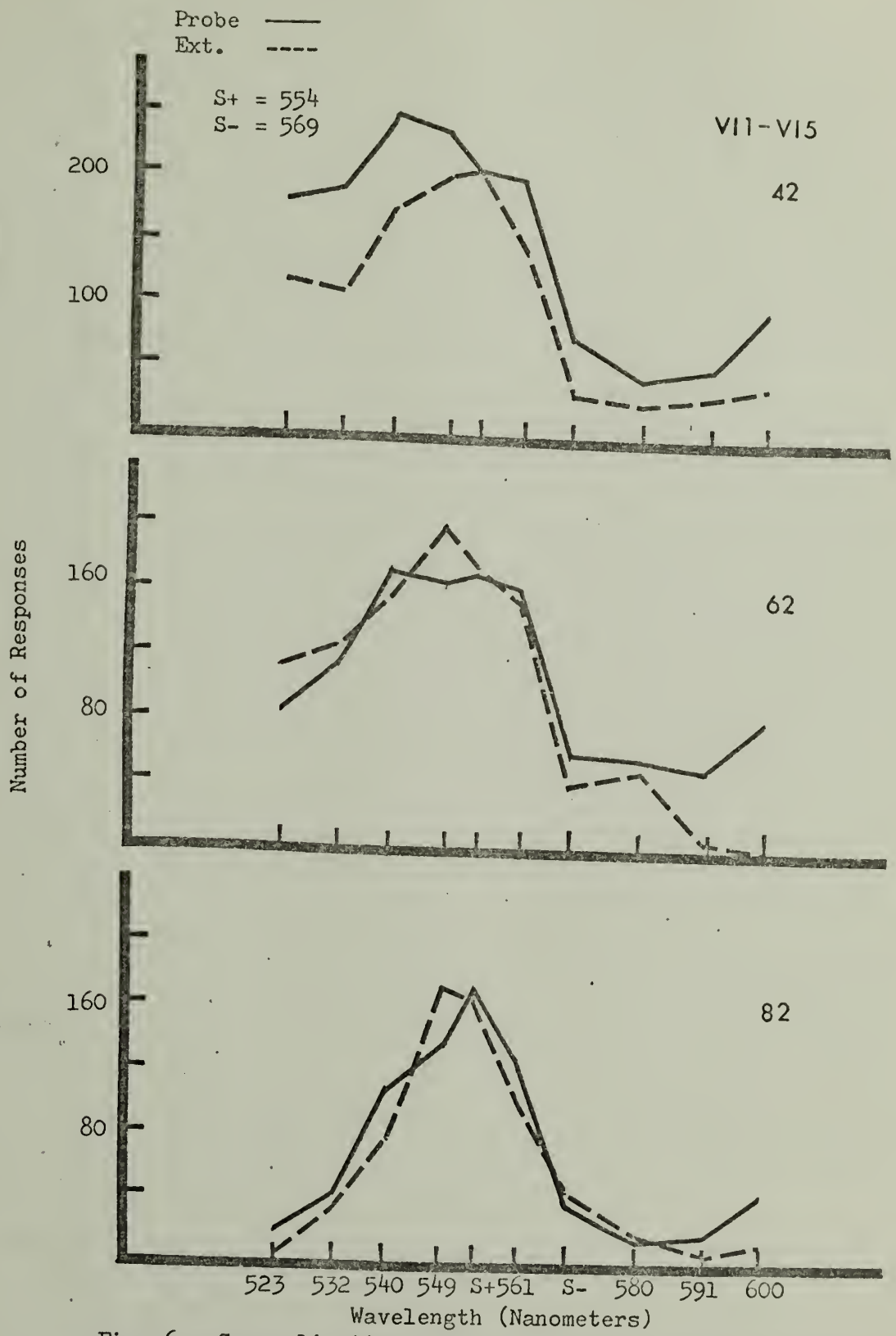


Fig. 6. Generalization gradients obtained during probe and extinction testing following multiple VI 1-VI 5 training.

subject 82 now showing peak shift, subject 62 increasing peak shift, and subject 42 showing a loss of peak shift but maintaining area shift. Again the finding of peak shift following multiple VI 1-VI 5 training is consistent with Terrace's (1966) results.

An unexpected result appearing in the gradients is the increased responding for all three subjects when the 600 nm stimulus was presented. This effect resulted in an upturn of the gradient on both sides of S- giving the appearance of a U-shaped depression in the S- region of the dimension. A smaller tendency for this same effect occurred in all three subjects receiving multiple VI 1-Ext training (see Fig. 4). Hanson (1959) also obtained a slight upturn in this region (600nm) following multiple VI 1-Ext training with similar stimulus values (S+ - 550nm; S- = 570nm). On the other hand, Terrace (1966) trained with the S- stimulus at the other end of the hue dimension (S+ = 579nm; and S- = 559nm) and did not report this upturn. It is possible that this upturn occurs only in the region of 600 nm and may indicate the existence of control by some stimulus dimension of chromaticity other than hue for which the stimuli in the 550nm region and those in the 600nm region are more similar. One obvious possibility is the saturation of the stimuli since the green(550nm) and red(600nm) regions of the spectrum are more saturated than the intermediate yellows. The IRT distributions obtained during probe testing appear in Fig. 7. As observed in the previous groups, the reduction of responding to test stimuli distant from S+ has resulted from a decreased tendency to emit the response pattern associated with S+ as evidenced by the relative invariance of the modal region of IRT categories. The peak

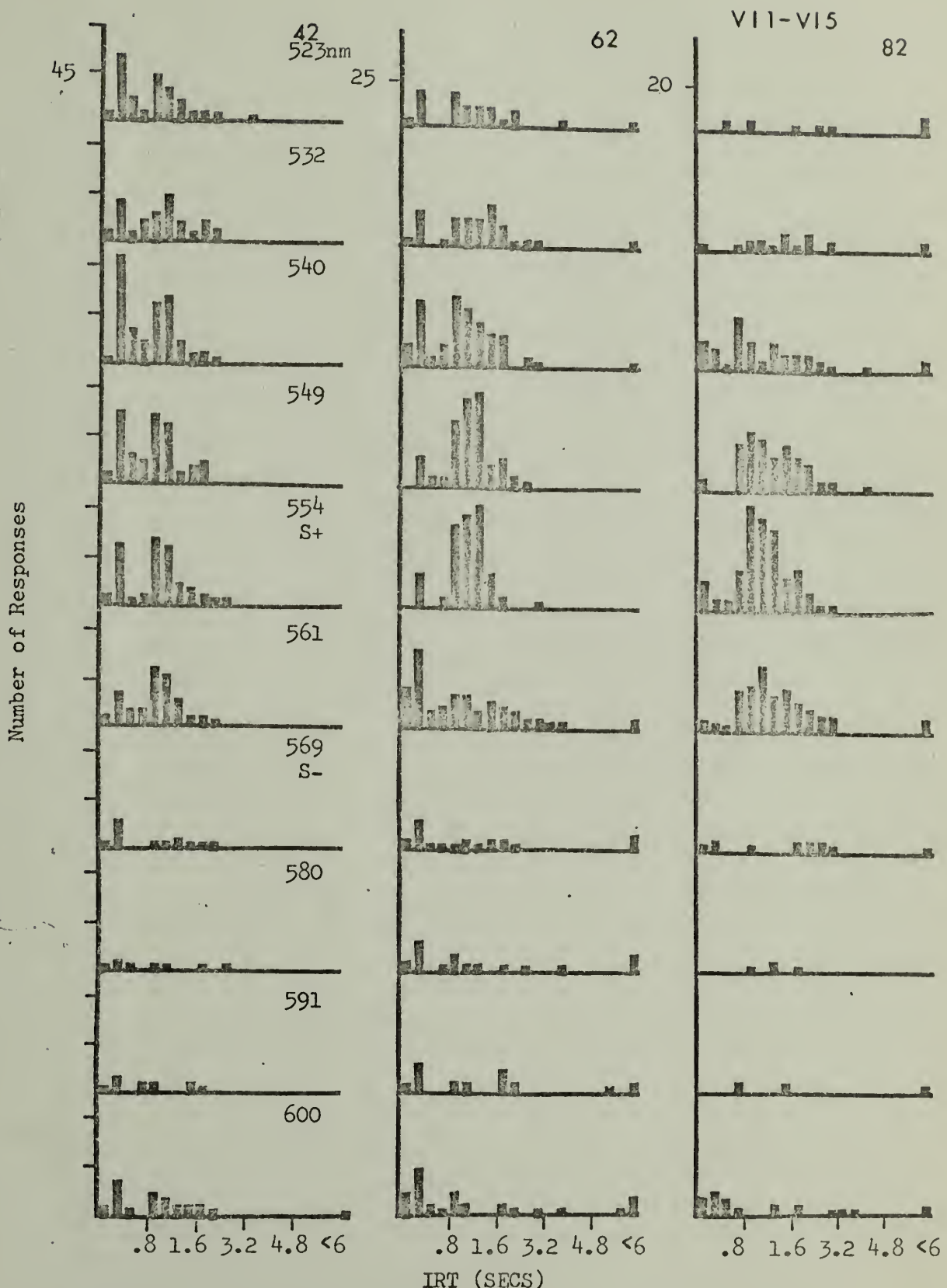


Fig. 7. IRT distributions obtained during probe testing.

shift effect is again seen as a result of an increased number of responses in the modal region. Inspection of the response pattern occurring when the S- stimulus (569nm) was presented indicates that the VI 5-min. schedule did not result in the development of a readily identifiable response pattern. The response pattern which did occur resembles to some degree the S+ response pattern but, of course, more depressed and without distinctive modes. The intended result of the establishment of a new mode at some longer IRT value clearly did not result. The possible reasons for this failure to establish a new mode will be discussed in a later section.

The second group trained with the multiple VI 1-VI 5 schedule received training identical to the previous group except that the training stimuli were further removed along the hue dimension (S+ = 554nm; S- = 591nm) . The response rates occurring during acquisition and discrimination training are presented in Fig. 3. Responding over the course of training was very similar to that of the previous VI 1-VI 5 group. The two subjects displayed in Fig. 3 again showed the contrast effect, however, the third subject (32) consistently responded at a low rate and showed no contrast effect. The response rate at the end of training for this subject was only 28 responses per minute.

The results from generalization testing are displayed in Fig. 8. As expected, the result of training with stimuli more distantly removed did not produce the peak shift effect obtained in the previous group. The reduction of peak shift as a function of the distance between the stimuli was found by Hanson (1959) and Sloane (1964). The gradients of both the probe and extinction testing procedures were in essential

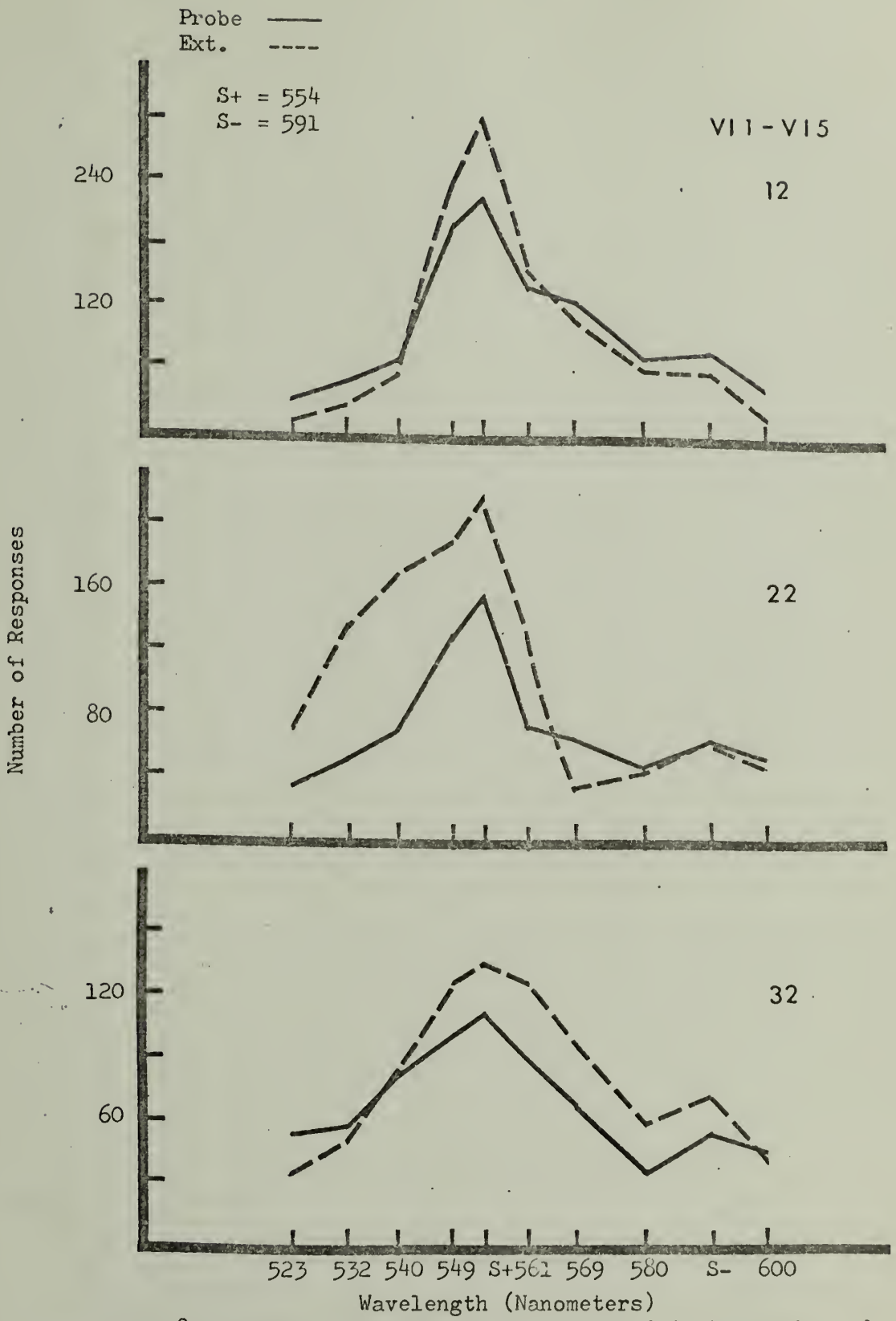


Fig. 8. Generalization gradients obtained during probe and extinction testing following multiple VI 1-VI 5 training.

agreement with one subject (22) showing an increased amount of area shift in extinction testing.

The finding of a decreased tendency for peak shift to occur with stimuli more widely separated is consistent with both the decision theory and the inhibition concepts. For the former, the S+ stimulus is viewed as being responded to less frequently as if it were S- and, for the latter, the S+ stimulus is sufficiently removed to escape generalized inhibitory effects.

The second finding of interest displayed in the gradients perhaps allows for differential predictions. The occurrence of the second, smaller, peak in the vicinity of the S- stimulus is in agreement with results reported by Collins (1971) and readily interpretable from a decision theory approach. The S+ stimulus is controlling a response pattern resulting in higher rates while the S- stimulus controls a pattern which yields a lower rate. Under conditions where the S+ and S- stimuli are relatively near one another (as in the previous VI 1-VI 5 group), the intermediate stimuli are responded to sometimes with the S+ pattern and at other times with the S-. This results in a depression in the gradient since under nondiscrimination training conditions these same points would result in only the S+ pattern being emitted. When these same training conditions are implemented with stimuli further removed, as in the present group, the intermediate stimuli are sufficiently removed from both S+ and S- such that neither response pattern will emerge and a rate lower than either the S+ or S- rates will result. For the inhibition concept, the occurrence of the double peak appears to be problematical. What is needed is an explana-

tion of how the same training procedures can produce an inhibitory gradient under one condition but an excitatory under the second.

The IRT distributions are presented in Fig. 9, and as was the case in the previous VI 1-VI 5 group, the stimulus associated with the VI 5-min. schedule failed to result in a distinctive response pattern. The results from subject 22, however, do indicate a trend was developing toward responding in longer IRT categories and perhaps with continued training a new mode would have emerged. The intermediate stimuli are not readily interpretable as mixtures of the S+ and S- patterns due to the lack of a distinctive S- pattern, but some of the points particularly stimulus 580, are showing the reduced tendency to result in either response topography.

DRH Training The response rates on the last day of acquisition training for the subjects given nondiscrimination training with the VI 1(DRH 1) schedule are presented in Table 1. As a measure of the efficiency of responding, the number of responses eligible for reinforcement (i.e. occurring within 1-sec. of the preceding response) are also displayed. The results of generalization testing for these subjects are shown in Fig. 10. The obtained gradients appeared symetrical and somewhat steeper than those obtained from the VI 1-min. nondiscrimination condition (Fig. 1). The obtained IRT distributions are shown in Fig. 11. The modal response pattern developed pr marily in the .2 and .4-sec. IRT categories accompanied by a reduction of the number of responses occurring at longer values as compared with the patterns obtained following VI 1 training (Fig. 2). Again, to the extent that responding occurred when test stimuli were presented, the responses were either

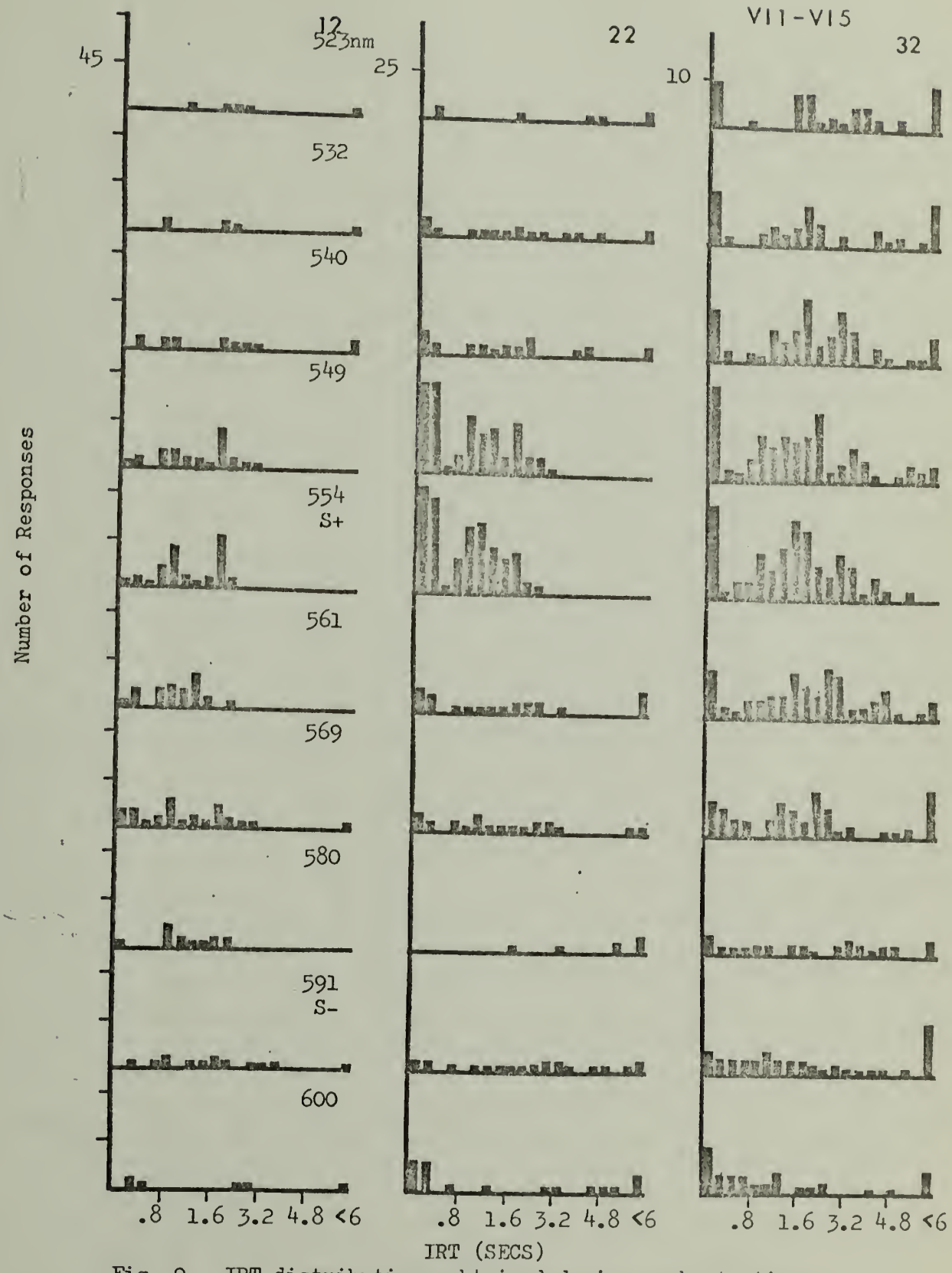


Fig. 9. IRT distributions obtained during probe testing.

Table 1

Responses on Final Day of Training

| Training | Subject | S+ Response* | S- Response |
|---|---|---|---|
| VI 1(DRH 1) | 73 | 1235(921) | |
| | 93 | 1651(1382) | |
| | 103 | 1930(1582) | |
| VI 1(DRH 1)-VI 1(DRL 3) (S- = 569nm) | 23 | 1142(890) | 428(252) |
| | 33 | 936(652) | 486(224) |
| | 43 | 1340(955) | 734(320) |
| VI 1(DRH 1)-VI 1(DRL 3) (S- = 591nm) | 53 | 1499(1028) | 431(223) |
| | 63 | 1180(741) | 505(166) |
| | 73 | 1597(1320) | 661(186) |

*Number of responses occurring within 25 50-sec. stimulus periods of S+ and 25 periods of S- on the last day of training. Numbers in brackets indicate the number of responses eligible for reinforcement (less than 1-sec. IRT for DRH and greater than 3-sec. for DRL).

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within the modal region or at long values. The effects of the DRH contingency were effective in generating consistent and distinctive response patterns and show even more clearly than previous distributions the failure of the response pattern to be altered during generalization testing.

VI 1(DRH 1)-VI 1(DRL3) Training The first group of subjects trained under these conditions received training with an S+ (VI 1(DRH 1)) of 554nm and S- (VI 1(DRL 3)) of 569nm. As described previously, an added contingency was imposed on the VI 1(DRL 3) component such that when a greater than 3-sec. IRT response was effective in delivering reinforcement any subsequent responses resulted in the food hopper

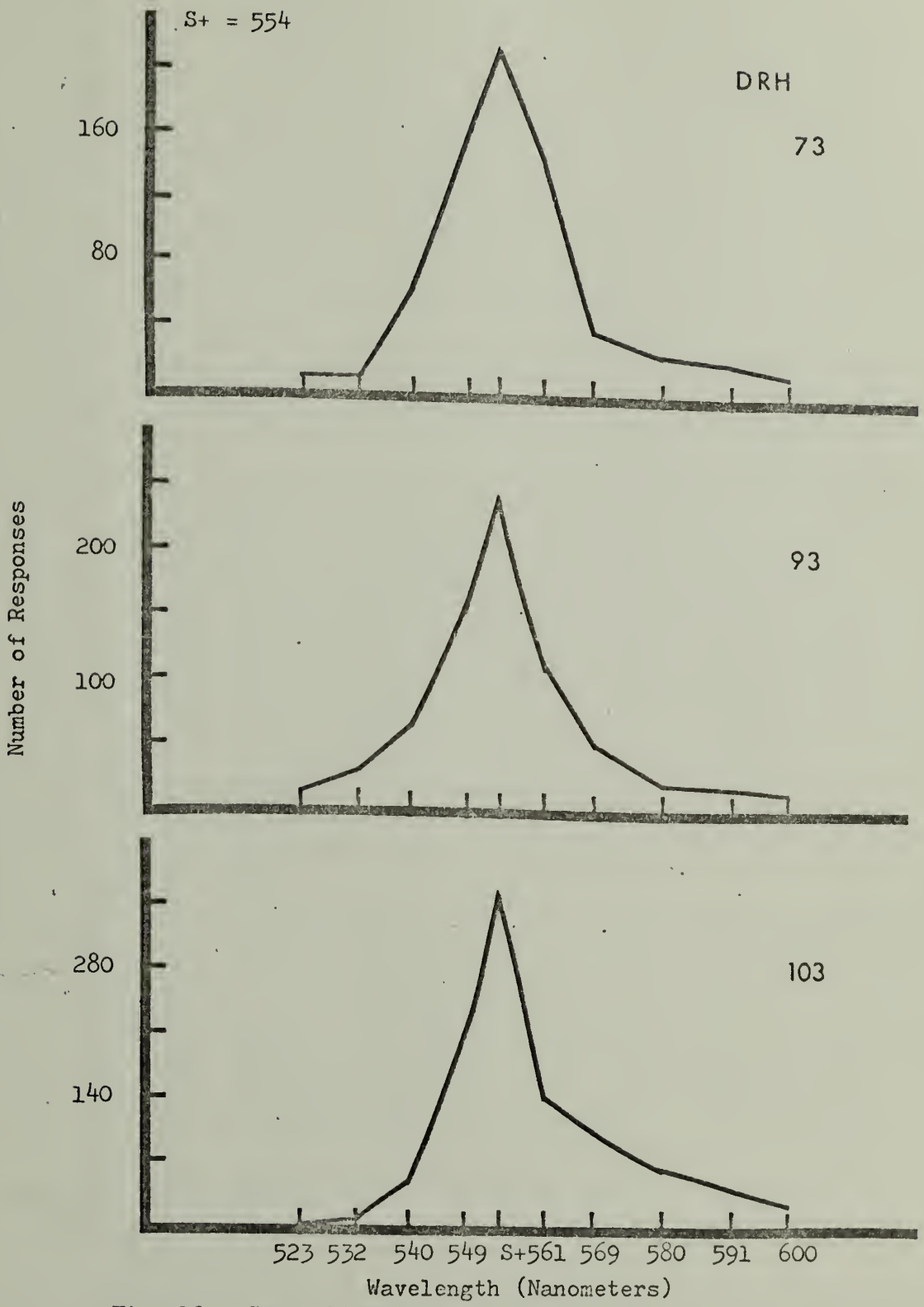


Fig. 10. Generalization gradients obtained during probe testing following VI 1(DRH 1) training.

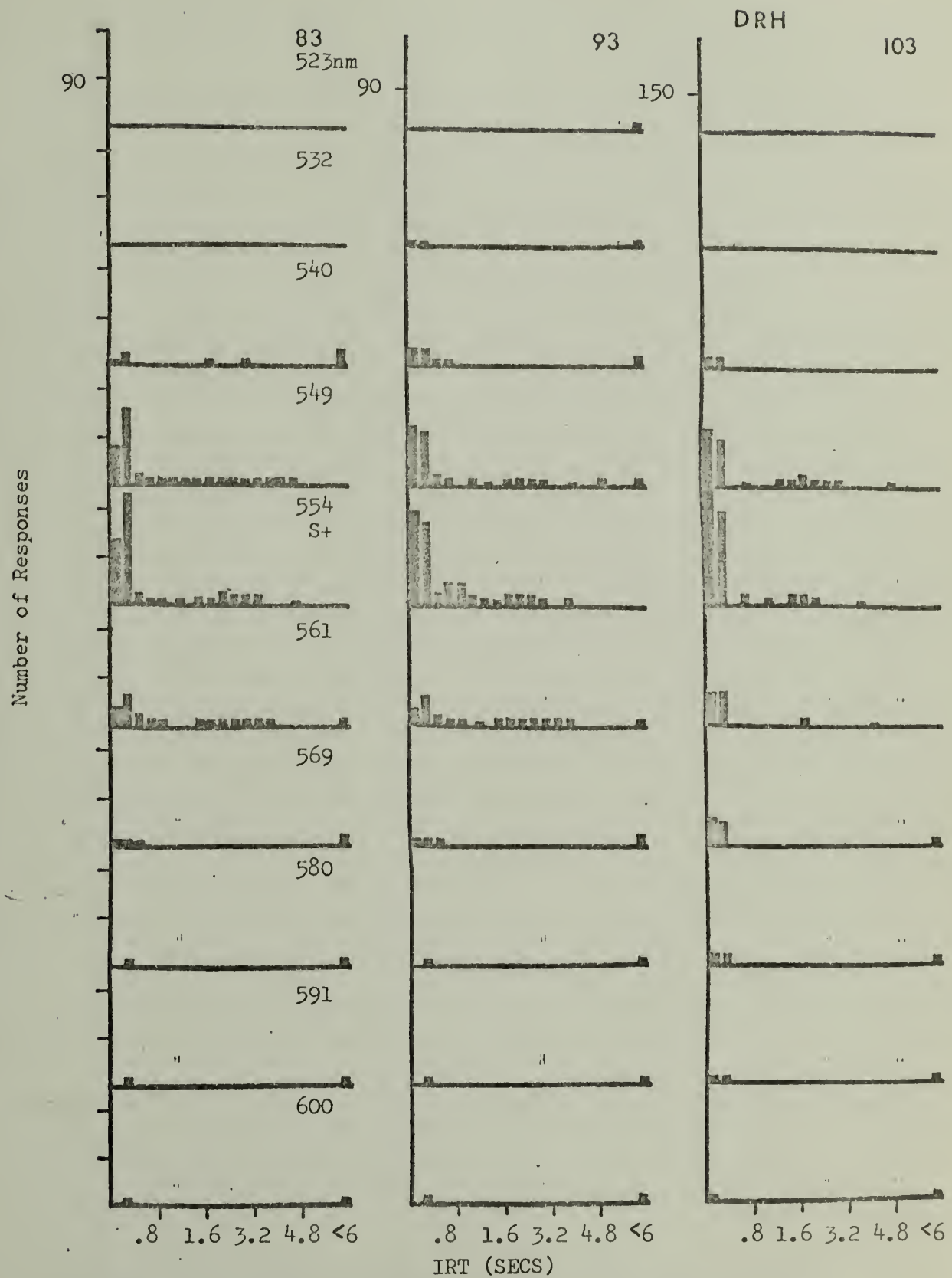


Fig. 11. IRT distribution obtained during probe testing.

being immediately lowered. This contingency was added in an attempt to eliminate a pattern of responding that several of the subjects were acquiring. This pattern consisted of pauses of approximately 3-sec. in duration followed by bursts of responding. The added contingency appeared to be effective in eliminating the pause-burst pattern. The number of responses recorded on the last day of training appear in Table 1. The three subjects trained in the present condition all displayed response patterns with approximately 50% of the responses emitted in the presence of S- having an IRT value greater than 3-sec.

The results of generalization testing are displayed in Fig. 12. The gradients show no evidence for peak shift and appear markedly steeper than the gradients obtained from the VI 1-VI 5 group trained with the same stimuli (Fig. 6). This sharpening of the gradient effect is most likely due to the extended amount of discrimination training required (16 days vs. 8 days) in order to develop stable DRL responding. The results of extinction testing agreed closely with the results from probe testing except in the case of subject 33 where a further sharpening of the gradient resulted.

The IRT distributions recorded during probe testing are presented in Fig. 13. The patterns of responding emitted in the presence of the S- stimulus (569nm) indicates that the VI 1(DRL 3) component was effective in generating a pattern displaying a modal value of approximately 3-sec. A second peak distribution also occurred in the short (.2-.4) IRT region indicating that the tendency to emit bursts during S- was not completely eliminated. The response pattern

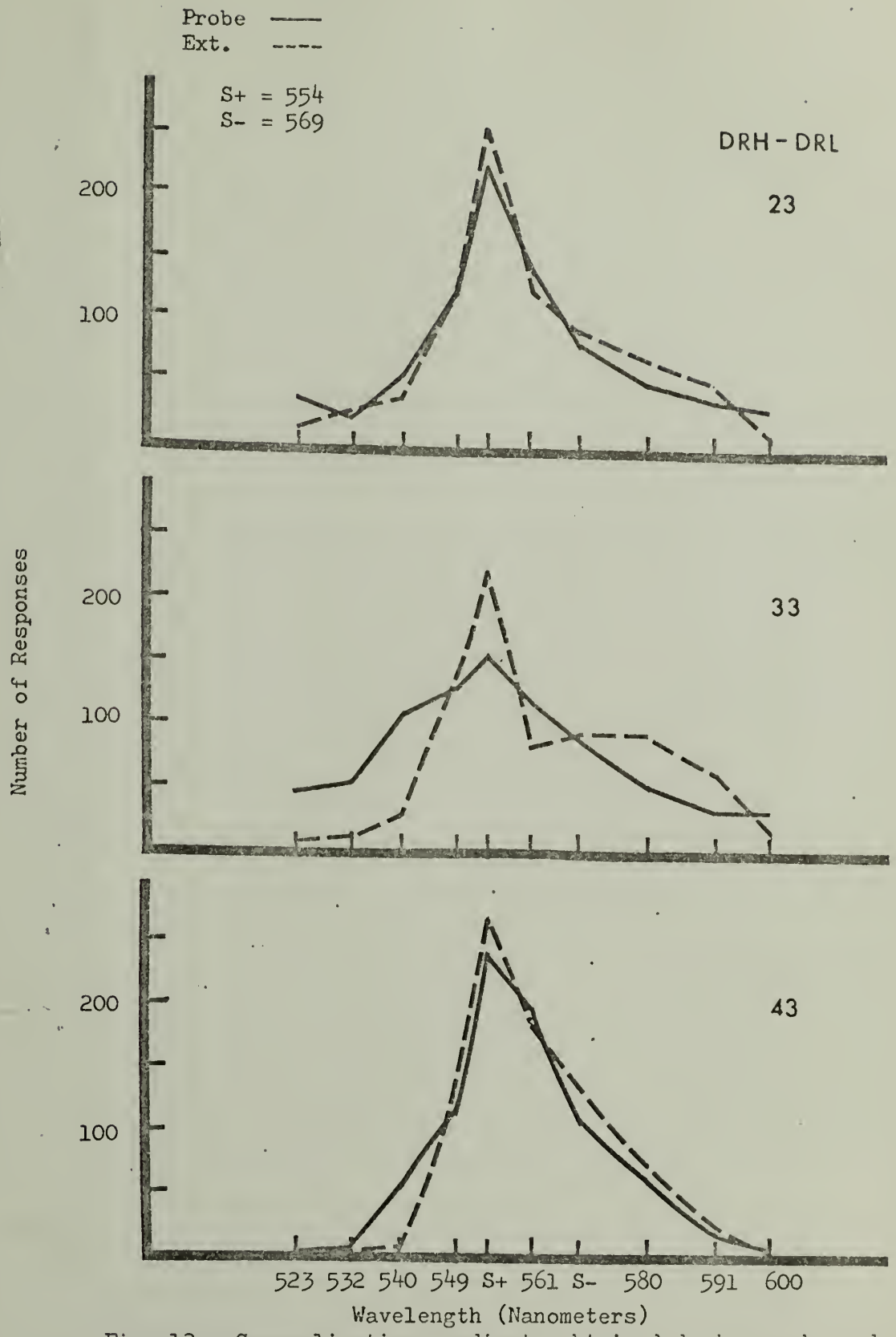


Fig. 12. Generalization gradients obtained during probe and extinction testing following multiple VI 1(DRH 1)- VI 1(DRL 3) training.

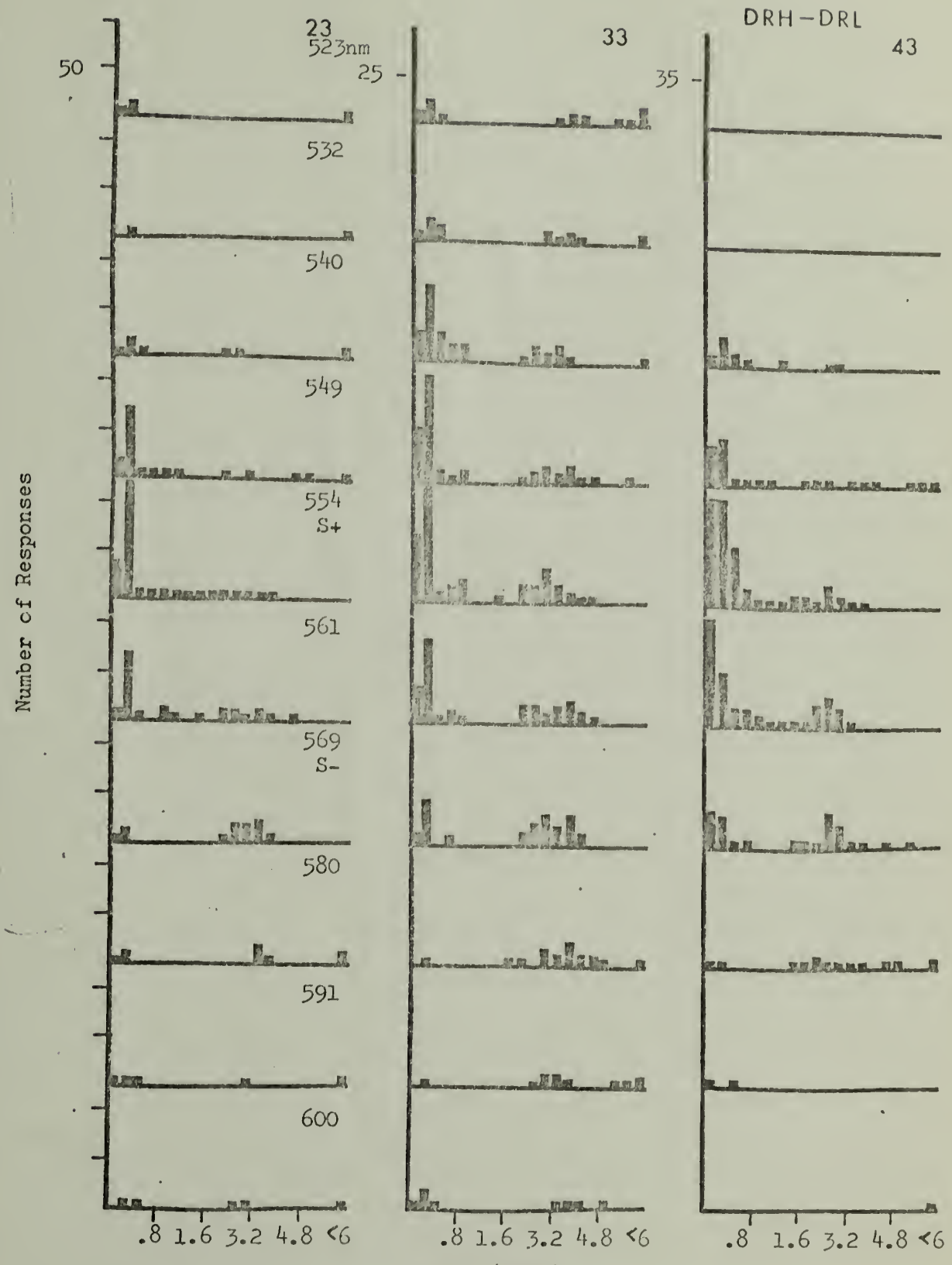


Fig. 13. IRT distributions obtained during probe testing.

displayed when the intermediate stimulus (561nm) was presented is clearly composed of a mixture of the response pattern emitted with S+ and the pattern emitted with the S- stimuli. The distribution shows the characteristic modal regions of both the S+ and S- patterns unlike the stimuli adjacent to S- (580nm). There also exists a tendency for the S- pattern to appear within the S+ distribution especially for subject 43 and even beyond for subject 33.

These results show that the mixture of response patterns does in fact occur during generalization testing. The situation appearing in the IRT distributions is equivalent to a discrimination involving discrete alternatives. Yet when these same data were plotted for the generalization gradients, a continuous change in responding is depicted. These results are consistent with those reported by Migler (1964) and Boakes (1969) involving a two-manipulandum task requiring different delays between responses; and lend further support to Migler's observation that the smooth and continuous generalization gradients often reported are the result of "inappropriate averaging" of different response patterns. The present results extends these findings to the single manipulandum situation using the successive discrimination procedure most often employed in generalization experiments.

The second group trained with the VI 1(DRH 1)-VI 1(DRL3) schedule received training with a S+ stimulus of 554nm and S- of 591nm. The generalization gradients obtained are shown in Fig 14. The probe testing gradient showed unexpectedly, one subject (53) displaying peak shift and second (73) with some degree of area shift. The extinction testing gradients showed a large increase in the amount of

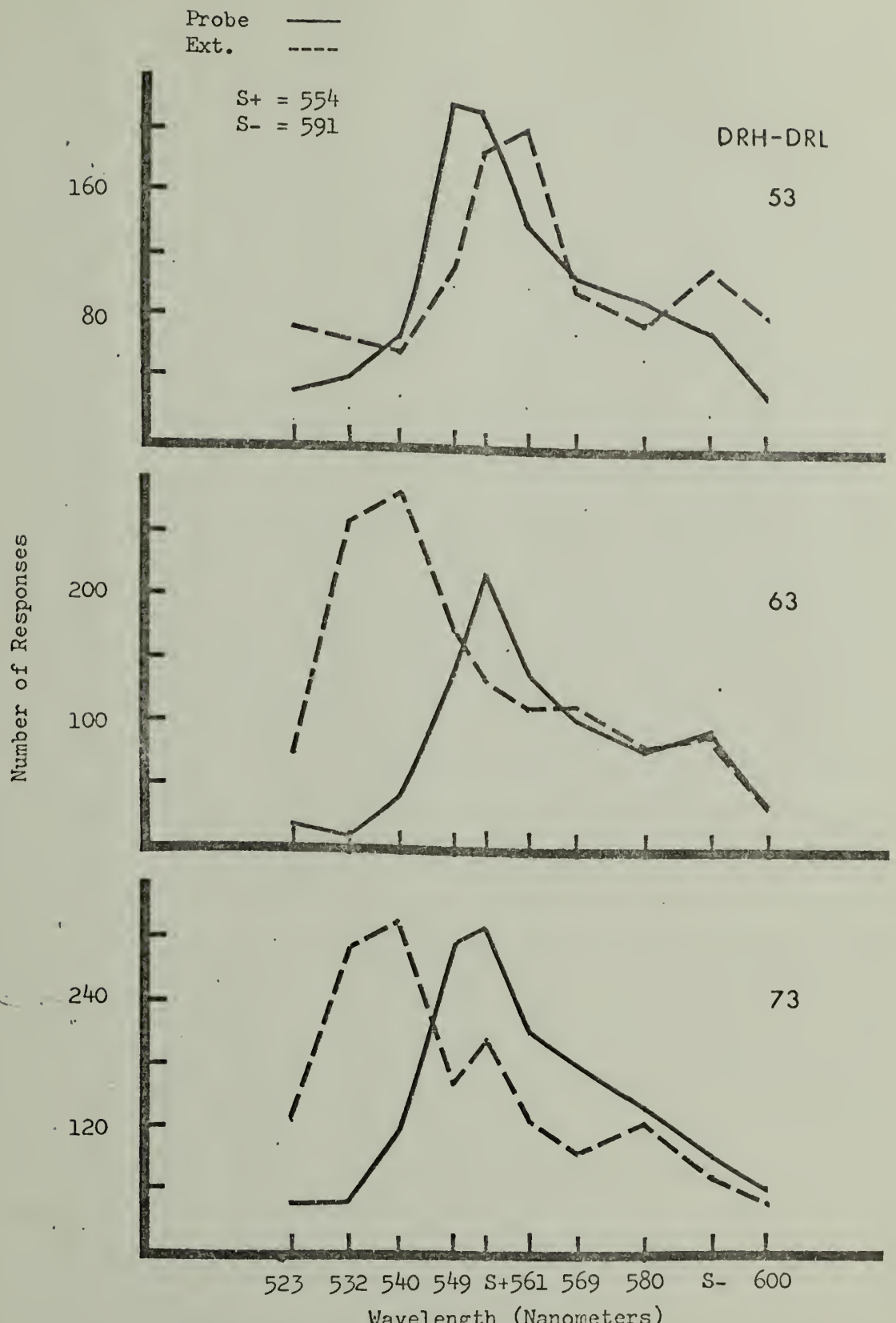


Fig. 14. Generalization gradient obtained during probe and extinction testing following multiple VI 1(DRH 1)- VI 1(DRL 5) training.

peak shift for two of the subjects, as had occurred previously for various other subjects. This result was unexpected since the VI 1-VI 5 subjects receiving training with these same stimulus values did not display peak shift. In addition, since the previous DRH-DRL group showed no peak shift, it would not be expected that the present group trained with stimuli more distantly removed would show this effect (Hanson, 1959). One possible explanation for this effect might exist in the fact that the two subjects showing the large peak shift (63 and 73) were also the two subjects showing the least efficient DRL responding as indicated in Table 1. Eventhough these subjects had received the same amount of training as the others, they may have been in an earlier stage of acquisition. Terrace (1966) has shown that peak shift diminishes as training is extended.

The IRT distributions (Fig. 15) show similar results to those obtained from the previous group. The greater separation of the stimuli in this condition allows for a clearer demonstration of the changing mixtures of the response patterns obtained as the test stimulus approaches S+ and S-.

Peak Shift

The greatest degree of peak shift obtained in the present study occurred during generalization testing using the extinction testing procedure. As noted previously, the extinction procedure often resulted in peak shift for subjects who showed no sign of peak shift during probe testing. There was also a tendency for the extinction procedure to result in a greater variability of responding to the same stimulus on different trials. These effects occurring in

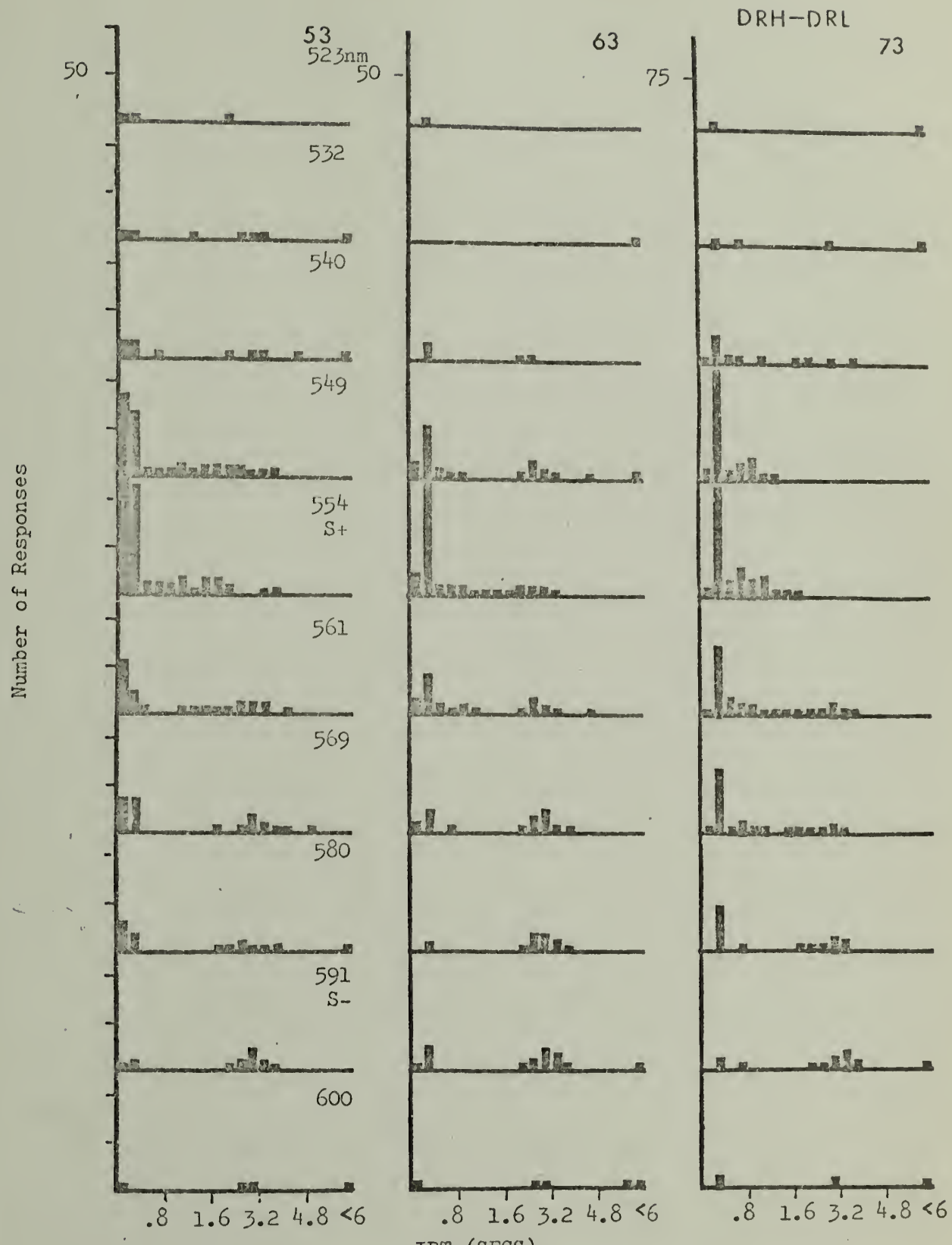


Fig. 15. IRT distributions obtained during probe training.

extinction testing are most probably due to the fact that the extinction testing procedure called for relatively long periods (40 trials) of testing during which no reinforcement was delivered. Eventhough the direct effects of extinction would be expected to result in only minimal reductions of responding, the indirect effects due to the removal of reinforcement during S+ would constitute a loss of a definite (as proven by reinforcement) reference stimulus. The probe procedure, on the other hand, calls for return to the training stimuli with reinforcement scheduled preceding each presentation of the test stimulus. The reference stimulus is, thus, maintained throughout testing and would be expected to result in more consistent responding. The probe procedure would therefore be expected to result in fewer detection "errors" by the subjects.

The IRT distributions obtained from three of the subjects showing a large degree of peak shift during extinction testing are shown in Fig. 16. Subject 31 showed an increased amount of responding to the 549nm stimulus. The IRT distributions obtained during extinction testing, when compared with those from probe testing (Fig. 5), show the S+ pattern was generally lower especially in the .2-.4-sec. categories. The pattern when stimulus 549nm was presented was generally increased in magnitude and resulted in peak shift. For subject 62 a similar increase occurred primarily in the .4-sec category. Subject 73 showed a more distinctive change in the response pattern. Again, comparing the distributions taken during extinction testing (Fig. 16) with these obtained during probe testing (Fig. 15), the pattern of responding when S+ was present in extinction testing appears very

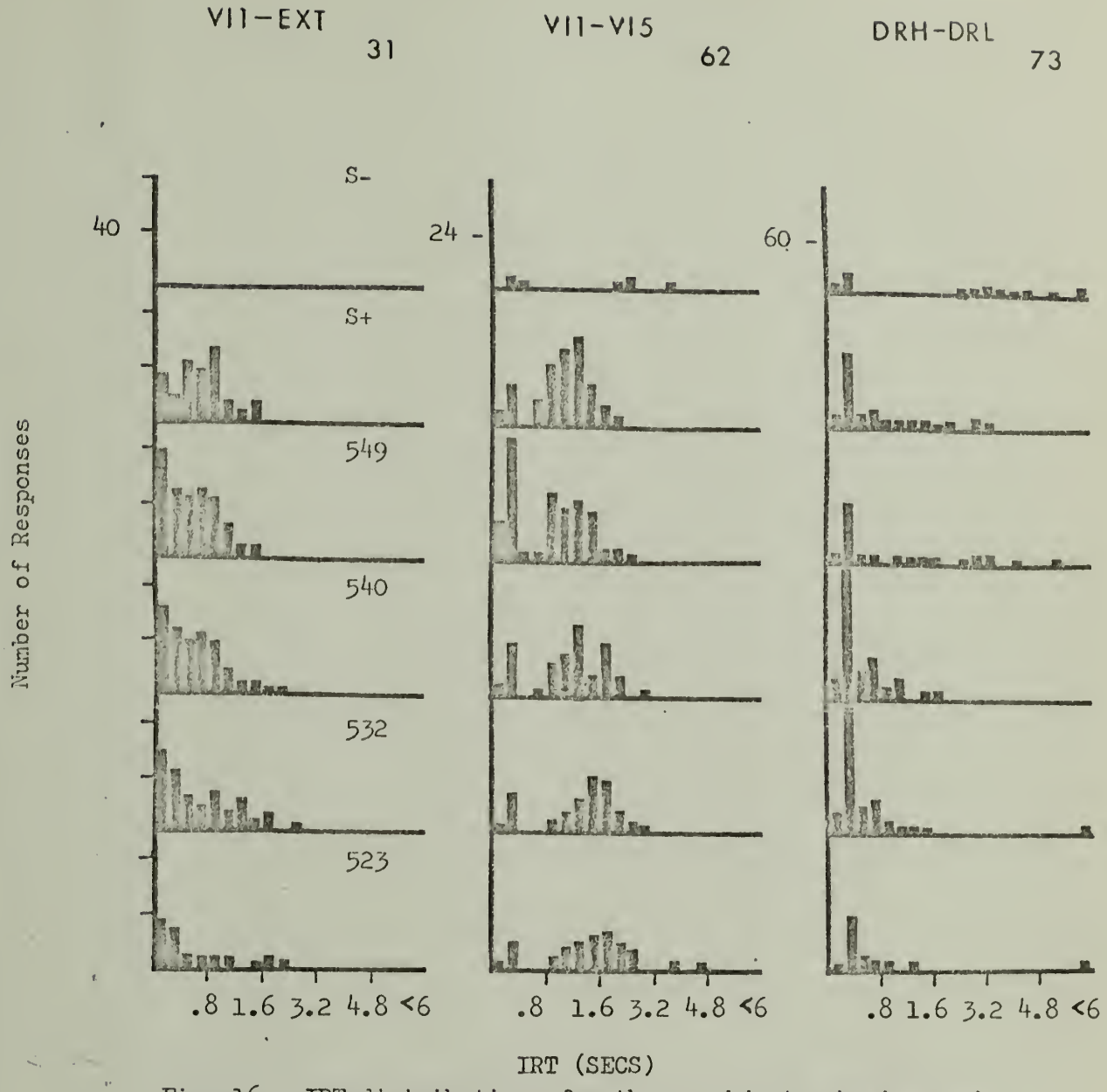


Fig. 16. IRT distributions for three subjects showing peak shift during extinction testing.

similar to the pattern resulting when stimulus 569 and 561nm were presented in probe testing. The patterns displayed when the 540 and 532 nm stimuli were presented in extinction testing appeared identical to the patterns displayed when S+ and 549nm were presented in probe testing. It appeared as if the response pattern along the entire testing dimension had been shifted towards the shorter wavelength values, away from S-.

Behavioral Contrast

As noted in the introduction the behavioral contrast phenomenon is problematic for a decision theory account. The hypothesis being investigated in the present study was whether the contrast effect resulted from an increased frequency of occurrence of the S+ response pattern as opposed to a shift of the modal IRT region towards shorter values. The IRT distributions occurring in the presence of the S+ stimulus on the last day of multiple VI 1-VI 1 training and the initial days of discrimination training when multiple VI 1-Ext was scheduled are presented in Fig. 17(top). In general, the increased rate of responding appeared to be due to an increase in the height of the modal region rather than a shift of the mode. But subject 52 does show some shift in the secondary mode from approximately 1.0-sec. to .6-.8-sec. There also appears to be little evidence of the predicted decrease in relatively long IRT's. In order to examine the longer but less frequent IRT's, the data was replotted to display the dwell time distribution (bottom, Fig. 17) as described by Weiss (1970). The dwell time values were obtained by multiplying the number of responses occurring in each IRT category by the mean, time value of that IRT

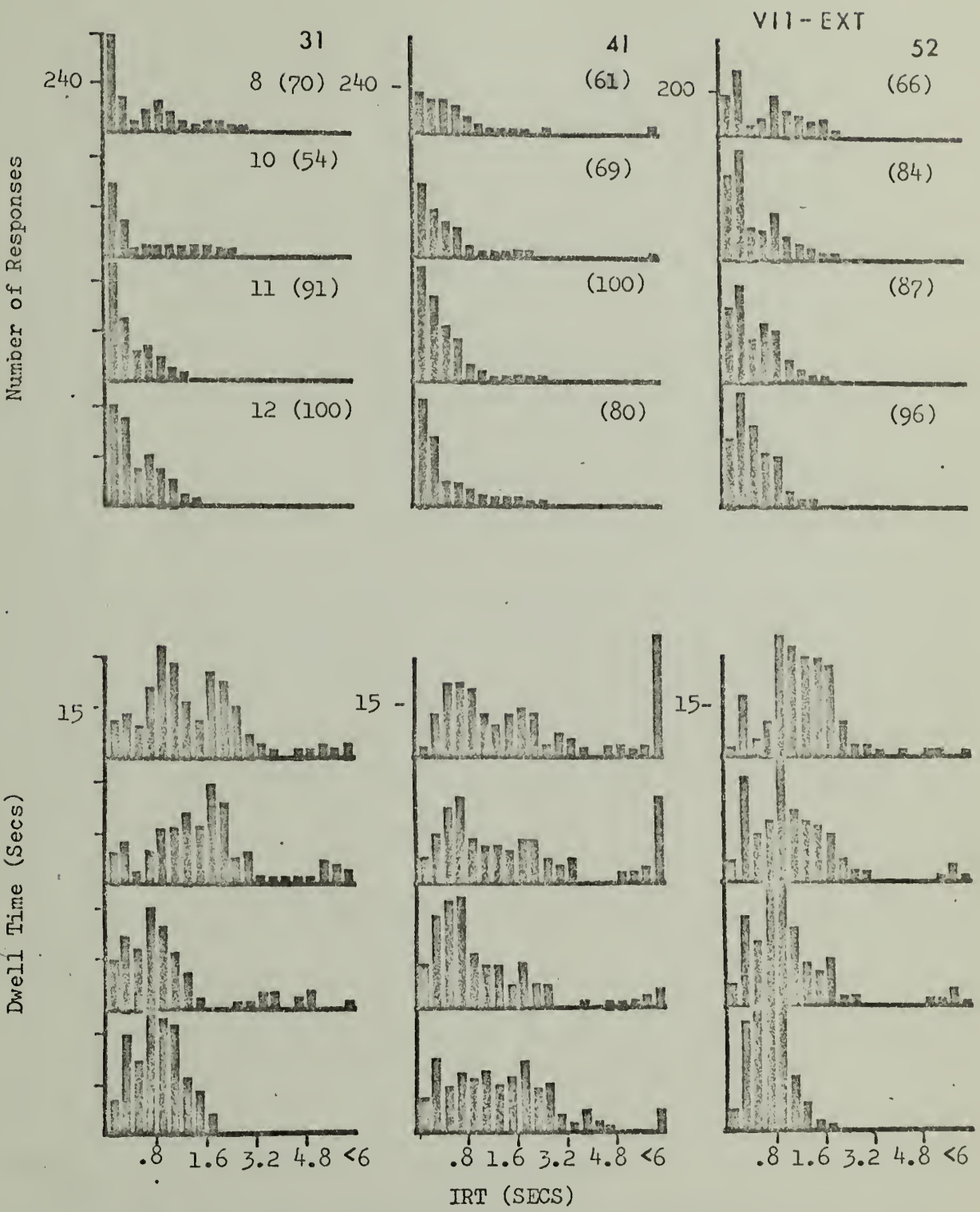


Fig. 17. Above: IRT distributions of responding during S+ on the last day of multiple VI1-VI1 (Day 8) and the initial days of multiple VI1-Ext training. Below: Same data showing time consumed by each IRT category. Numbers at right indicate day and rate (in brackets).

category. This measure has the effect of weighting progressively the longer IRT's. The dwell time plot thus indicates the actual amount of time that the subject consumes in emitting responses within each IRT category.

Inspection of the dwell time data reveals that for subject 31 some reduction of longer IRT categories did occur, for subject 41 a much greater reduction, but for subject 52, little reduction. The data from subject 41 is consistent with the hypothesis that the effect is due to the tendency of the subject to more frequently emit the S+ response pattern. The data from subject 31 is less so, and the data from subject 52 suggests the possibility of a modification of the basic response pattern. Based on these results, it is difficult to reach a firm conclusion on the nature of the contrast effect. More data is needed, especially from subjects showing a lower rate of responding prior to the development of contrast. All of the subjects in the present group had an unusually high rate of responding prior to discrimination training.

Effects of Reduced Reinforcement

The other major effect of discrimination training in addition to the contrast effect is, of course, the reduction of responding in the presence of the S- stimulus. The data from three subjects undergoing discrimination training and, for comparison, three subjects placed in straight extinction appear in Fig. 18. The data displayed are the response patterns generated over the initial days of extinction and discrimination training. The changes in the IRT patterns as a result of non-reinforcement appear remarkably similar to the changes occurring in generalization testing as the stimulus becomes more

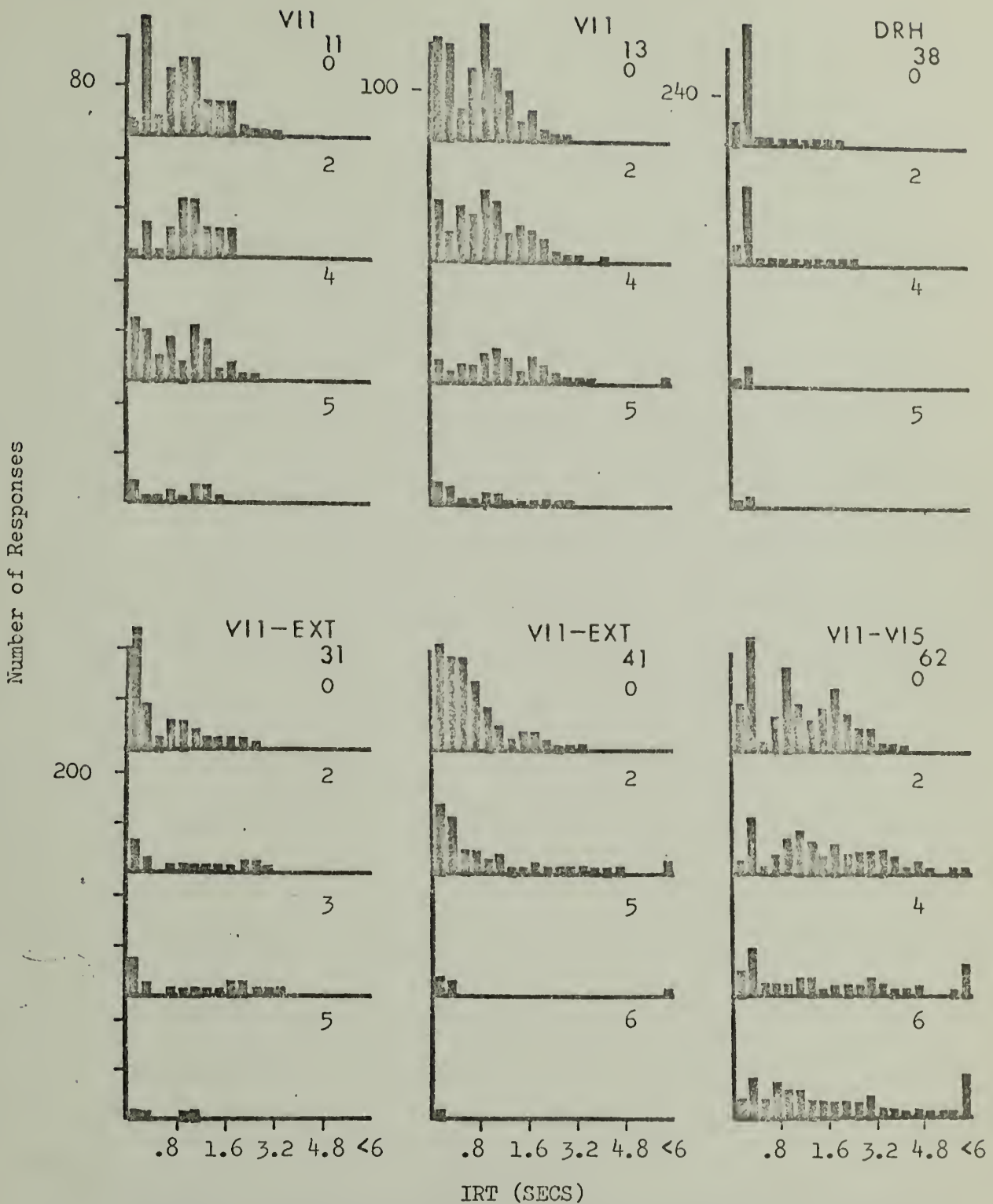


Fig. 18. IRT distributions taken during extinction of responding following nondiscrimination training (above) and during extinction of responding to S- during discrimination training. Numbers at right indicate número of days of extinction or discrimination training.

dissimilar to the training stimulus. In both cases, the changes are best described as a reduced tendency for the S+ response pattern to occur as indicated by the stability of the modal region of the distribution. There is no evidence of a reduction of response strength which would result in the shifting of the mode to longer IRT values. These results also indicate that the response pattern as revealed in the IRT distributions displays another of the characteristics of an operant, i.e., the tendency of the pattern of responding, itself, to be reduced as a function of time in extinction.

Subject 62, undergoing VI 1-VI 5 differential reinforcement shows changes similar to those occurring with VI 1-Ext training except, of course, that responding is not completely eliminated. The response pattern developed during VI 1-min. training appears to be only depressed by the VI 5-min. schedule. The S+ response pattern is simply occurring at a lower frequency. It is not clear whether extended training with the VI 5-min. schedule would eventually result in the formation of a new modal region of the IRT distribution. It would seem that a reasonable case could be made that once the pattern of responding has been established on the VI 1-min. schedule, the reduction of reinforcement during the VI 5-min schedule simply results in a lower frequency of the VI 1-min. response pattern. It may be necessary to begin training with the VI 5-min. schedule in order to develop a characteristic response pattern consisting of a longer IRT mode. Although it is highly speculative at this point the unexpected intransigence of the response pattern once established may have implications for some related finding concerning peak shift and contrast. Terrace (1966) and Weisman (1969) have both

obtained data showing that the multiple VI 1-VI 5 schedule does result in contrast, peak shift, and inhibitory gradients when the pre-discrimination acquisition phase involved the use of the VI 1-VI 1 schedule. However, if the schedule in effect during the initial training phase was multiple VI 5-VI 5 , then neither contrast nor peak shift occurred. If initial training is critical in establishing basic response patterns, then the groups initially trained with VI 5-min. may show long term effects of this training and not be capable of emitting the increased rates of responding occurring during contrast and peak shift.

# SUMMARY AND CONCLUSION

One of the major points made by the present study was the demonstration that intermediate rates of responding to stimuli intermediate between S+ and S- were due to a mixture, in varying proportions, of the response patterns previously developed in training with the S+ and S- stimuli. This effect was obtained with the successive discrimination procedure utilizing a single manipulandum, the procedure typically used in those studies generating evidence for a continuous generalization function. This study joins a growing list of studies demonstrating under a variety of different conditions and using different species that intermediate responding to intermediate stimuli does not occur. In addition to the studies discussed in the introduction, Boakes (1969) replicated Migler's (1964) study using pigeons and a two key procedure; Cross and Lane (1962) using human subjects failed to find intermediate responding of a vocal response; Cumming and Eckerman (1965) and Wildemann and Holland (1972) trained pigeons to peck at different locations along a continuous strip and failed to find responding in the intermediate region when intermediate stimuli were presented. Certainly response repertoires which have the ability to change continuously when small differences in the stimuli occur are important in many skilled forms of behavior (Skinner, 1953). However, as Wildemann and Holland (1972) suggest, these continuous response repertoires are probably acquired as a result of reinforcing responses to specific stimuli and not be presenting stimulus values intermediate to values previously associated with reinforcement.

A second major point of this study was the finding that peak shift

resulted under training conditions such that the stimuli adjacent to S+ were more frequently detected as the S+ stimulus than the S+ stimulus itself. This occurs due to the tendency for the S+ stimulus to be frequently detected as S-, particularly when the S+-S- distance was small. It was also demonstrated that the decision theory analysis could as easily interpret the depression in the gradient as the inhibition concept and could, in addition, explain the finding of two peaks in the gradient when the stimuli were further removed.

Another result was the obtaining of evidence suggesting that the increase in responding due to behavioral contrast may perhaps be best described as an increased frequency of emission of the S+ response pattern. Although the evidence on this point was equivocal, it merits further research. An interpretation of this type, if supported would be more parsimonious than the increased emotionality hypotheses (Terrace, 1966; Amsel, 1958).

Another result consistent with decision theory was the finding that the effects of non-reinforcement on responding resulted in a decrease in the frequency of the reinforced response pattern but not in a shift of the modal IRT. This result is also consistent with many recent studies concluding that the IRT displays all the characteristics of an operant. Wilkie and Pear (1972) have recently demonstrated that the rate of emission and the temporal distribution of the occurrence of a reinforced IRT shows schedule effects (e.g., FI scallops). Although, it is still possible (Reynolds and McLeod, 1971) that the evidence is not compelling.

In conclusion, the evidence from the present study and the related

studies discussed are strongly suggestive that a decision theory approach to many of the problems encountered within the learning literature will prove fruitful.

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